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Behavioral Variability, Learning Processes, and Creativity: Final Technical Report

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This research investigates properties of human behavioral variability. The concept of behavioral variability is discussed in the theoretical framework of learning theory, developmental psychology, and the psychology of intelligence and creativity. Relevant aspects of scientific literature are reviewed. Experiments investigate the effects of environmental factors on the variability of sequences of responses as a function of age, of cognitive capacities, and of educational background (for the adult subjects). Researchers used an experimental device that allowed for a number of equally efficient behaviors. Strategies used by subjects were recorded in various situations with differing degrees of constraint on freedom. Findings indicate that the performance, the variability, and the capacity to adapt to environmental contingencies are limited by the subjects' developmental level but they are not directly tied to cognitive capacities or cognitive styles. The mastery of the task seems to be slightly related to the educational background. The results suggest that variability is an inherent dimension of behavior, sensitive to its

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consequences, and that the potential for variation depends on the mastery of a set of basic behavioral units. The results support the idea that variability can be approached within the frame of learning theory and that, as a basic aspect of problem solving and creativity, it can be influenced by teaching.

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Main team

Marc Richelle, Senior Investigator
Bruno Boulanger, Research Associates, Fellow of the FNRS
Anne-Michelle Ingebos, Research Associates
Martine Lahak, Research Associates
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Christine Goffinet, Secretary

Occasional Contributions

Philippe Schyns (now a graduate student at Brown University), design of the animated presentation of the Matrix procedure on the Commodore computer

Armando Machado, graduate student, Fellow of the Portuguese National Research Council, animal research

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BEHAVIORAL VARIABILITY, LEARNING PROCESSES, AND CREATIVITY: FINAL TECHNICAL REPORT

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Moreover, presentations of parts of the material reported have been made in various scientific meetings:

- How to train pigeons to vary their sequences, by B. Boulanger. Poster presented at the Annual Meeting of the Belgian Society of Psychology. Bruxelles, Belgium, May, 1986.

- Conditioning variability in humans: A developmental approach, by B. Boulanger. Paper presented at the Second European Meeting of the Experimental Analysis of Behavior, Liège, Belgium, July 1988.

- Symposium on Behavioral Variability in Learning and Cognitive Processes. Organized by M. Richelle as an invited symposium at the Sidney International Congress of Psychology, August 26-September 3, 1988. With participation as invited speakers of J. Delius, Konstanz (FRG), J.E.R. Staddon (Duke University, U.S.), P. Bovet (CNRS Laboratory, Marseille), G. Lautrey (Université René Descartes, Paris).

  M. Richelle's introductory paper, "Looking at variability in its own right" was a shortened version of chapter 2.1.

- M. Richelle, main investigator, has been invited to lecture on behavioral variability in various places during the period covered by the contract. These include the Hungarian Academy of Sciences in Budapest, the University of Neuchâtel in Switzerland, the University of Lisboa in Portugal, and the University of Lille in France.

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CHAPTER 1

OVERVIEW

1.1. THEORETICAL FRAMEWORK

1.1.1. ROUTINE SKILLS AND FLEXIBILITY

The concern for improved efficiency in problem solving and decision making in novel situations is central in all contexts of the modern world where adjustment to fast changes is required. This is typically the case in industry and in all fields, including the military, in which humans are confronted with rapidly evolving technologies. While firmly established skills, ready for highly automatized performance, are obviously needed, it seems desirable that they be complemented by flexibility when programmed action is not available to solve unexpected difficulties. The balance between routine, highly efficient control and flexible appraisal of a novel situation raises one of the most complex problems in applied psychology of learning and intelligence. The fact that current technology, based on highly automatic systems and robotics, has taken over, in a more efficient and safer way, tasks that were previously performed by human operators, has had the consequence of leaving the latter with the specific responsability for dealing with that part of reality that cannot be routinely treated by automata. But in order to react efficiently in unexpected situations, the human agent is, to a large extent, supposed to integrate, in parallel with automatic devices, the routine treatment as it goes on undisturbed by unusual events, so that he can react with correct knowledge of the state of affairs when such events occur.

This paradoxical complementarity between routine and flexibility is most important in the military context, pervaded as it is by modern technology, but it seems at odds with the traditional approach to the training of military men. Military training has been aimed at endowing soldiers with a set of highly automatized behaviors and a stable tendency to obey orders - that will hopefully function in all battlefield or similarly critical situations, and resist interferences of emotional stress. However, in so far as emergency situations involve, more often that not, essentially non predictable aspects, it has been increasingly recognized that routine training is not enough, and can indeed sometimes lead to absurd or totally inefficient solutions.

Therefore, the challenge for those which are in charge of training is clearly to find the adequate combination of automatism and flexibility. Or, putting it another way, to ensure that useful automatisms are available to the individuals as they are needed, while preserving their capacity for varying from programmed action when necessary. Much is known, from a long tradition in practical training of men in various contexts, about the efficient ways to build a repertoire of simple and complex behavioral units finely tuned to predictable situations. Many laws of learning, as described by psychologists - progressive shaping, repetition, distributed vs massed learning, effects of reward, punishment, knowledge of

results, and the like, - correctly fit to the educational strategies put to work.

While we can characterize fairly well what a given motor habit, or a given information processing are, we are not able to describe clearly what are the properties of those "flexible behaviors" which, we feel, are useful for adaptation to novel situations or production of creative works. This might be the reason why we resort to general abstract terms like "flexibility" rather than to concrete and operational definitions.

For all pratical purposes, the main question, however, is not so much "What is the nature of psychological or behavioral flexibility ?", but "Can it be trained, and if so, how can it be trained?". These are the questions that have been addressed to in the present research project. They have not been dealt with in appplied, field situations, but in much more limited laboratory situations. It is assumed that experimental models in the laboratory can help in providing new insights about this little understood aspects of human adaptation in real life.

1.1.2. THE ISSUE OF CREATIVITY

At this point, it is advisable to clarify terminological matters. We have been using, up to now, the word flexibility, and we have occasionally referred to creativity. These are words familiar to everyone, which make them convenient in conveying ideas to a non specialized audience, but can also be a source of confusion. For theoretical and methodological reasons which will be exposed at length in chapter 2.1. (Looking at variability in its own right), the word behavioral variability has been preferred. The core of the argument can be summarized in non-technical terms by first reminding the reader of some aspects of the psychology of creativity in the last few decades. The approach taken here will be best characterized by contrasting it against that background.

While some psychologists had been occasionally interested in creativity before that time, renewed and systematic concern for that elusive aspect of human activity has developed roughly since the fifties. It was related with a shift, in education, from a view of school as a place where knowledge is transmitted to a conception of school as an environment in which creative persons are - or should - be fostered. However, a less idealistic account of the renewed interest for creativity can be suggested : in the context of the "cold-war" and of competition between the two superpowers, there had been, in the fifties, among political and educational circles in the United States, acute awareness of the inefficiency of schools, especially with regard to science education. The solution was looked for in the magic concept of creativity.

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Whatever the respective part played by changing views of education and by sociopolitical anxiety, the dominant tenet tended to oppose creativity and knowledge acquisition. The first was seen as an inborn potentiality, expected to express itself spontaneously in the absence of obstacles, while the latter was viewed as the result of social conditioning - with all overtones attached to this word. In an extreme version, the less educational institutions would interfere with the developing individual, the more likely would his/her creative potential emerge. As one prominent educationist put it : "Creativity cannot be taught, like physics; it can only be liberated" (Schwartz, B., 1973).

In so far as school education had been assimilated with a consistent, rational undertaking, creativity was felt as escaping rationality, as implying essential ingredients of an emotional, rather than rational nature. Support for this view was provided later by appealing, in a rather simplistic manner, to the recently discovered hemispheric specialization of the human brain.

Though derived from a quite different branch of psychological research, psychometric approaches to creativity did not suggest any essentially distinct view of creativity. Dichotomies such as divergent vs convergent thinking, field independence vs field dependence, explorer vs assimilator cognitive style, fluidity vs crystallized thinking, and the like, where the first term is assimilated with a creative mind and the second term with conformity, imply that creativity is to be understood as a personality trait or factor rather than as a dynamic aspect of action and thought, and sanction the view that a break exist between creativity/flexibility on one hand and learning/problem solving on the other. It does not provide any useful hint as to the possible links between the two opposite domains. Moreover, a personality or mental trait is not the sort of thing that can be changed or improved, which means that this approach leaves little hope as to the feasibility of educating people to creativity.

1.1.3. THE EVOLUTIONARY MODEL

The view adopted here is radically different, which does not mean that it is not backed by an important tradition of theoretical thinking in modern psychology and in other sciences. It assumes that, whatever the differences in the complexity of behaviors or underlying processes involved, simple learning, problem solving and so-called creative behavior are all located along the same continuum, and that common basic mechanisms are at work in all forms of adaptive behavioral change. These mechanisms are best understood by referring to the analogy of biological evolution - a theoretical frame that has shaped modern thinking not only in biology, but in many aspects of psychology, anthropology, and even of physical sciences (see Prigogine & Stengers, 1979, 1988).

We shall not engage here into the intricacies of the evolutionary model - these will be elaborated further in chapter 2.1. Let us summarize the main relevant points as follow :

(1) What makes the evolutionary model an inspiring one for our present concern, is that it has to account for the emergence of novelty (novel living forms), which is also our problem as we have to account for learning, problem solving and creative behavior (any bit of learned behavior is *novel* in the repertoire of an individual, as is the solution given to a problem; creative acts are *novel* by reference to a whole set of shared cultural behaviors and products);

(2) The process at work involves two major elements, i.e. variation (of the genetic material, through mutations and recombinations by sexual reproduction) and selection (environmental conditions, the pressure of which eventually results in survival). We can think of learning, problem solving and creative behavior also as involving a process of selection upon a fraction of the behavioral and cognitive activities of an organism. In other words, if a selective process is to operate at all, we need some variations to start with. No change is to be expected, nothing new is likely to occur if there is no variability in the system.

The concepts of variation and variability are not easy to deal with, however. Especially in the tradition of psychological thinking, still much dominated by a restricted definition of a scientific approach, variability has generally been looked at as a property of data that most researchers will rather like to eliminate. Either it is viewed as reflecting the imperfections of the scientist's tools of observation - and the remedy is to work out refined techniques - or it is conceived of as reflecting the imperfections of nature, about which nothing can be done, but which can be minimized, or neutralized, by considering only ideal patterns (central tendencies, types, clear-cut categories, ...) ignoring variations around them as mere <u>deviations</u>.

There are a number of reasons that explain why, throughout the history of psychology and up to now, psychologists have been treating variability in that way rather than looking at it in its own right. These will be shortly discussed in chapter 2.1.

The consequence of that state of affairs is that very few study have been focussed on behavioral variability, or the nature and sources of behavioral variations.

The fields of animal and human learning and problem solving is typical in that respect. In the particular area of operant conditioning, notwithstanding the theoretical interest in the evolutionary analogy, the emphasis has been put on the control exerted by so-called contingencies of reinforcement (the set of environmental conditions that shape and maintain behavior), which can be identified with the "selective pressure" variable. This has led to the de ply misleading interpretation, that is widespread among psychologists as well as among laypeople, that operant conditioning is about routinely

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repetitive, stereotyped behavior. Little attention has been given to variations, which, however, are crucial for the learning process itself (the few relevant empirical studies and theoretical contributions will be reviewed in chapter 2.2).

Similarly, in studies of problems solving, behaviors not leading to the solution are usually overlooked, or recorded as errors, rather than systematically analysed as useful approximations. In the study of cognitive activities, Piaget has taken a quite different stand in focussing on the properties of a subjects' reasoning rather than the adequacy of its outcome to the rules of logic. The present study owes much to his theoretical approach and to his experimental ingenuity.

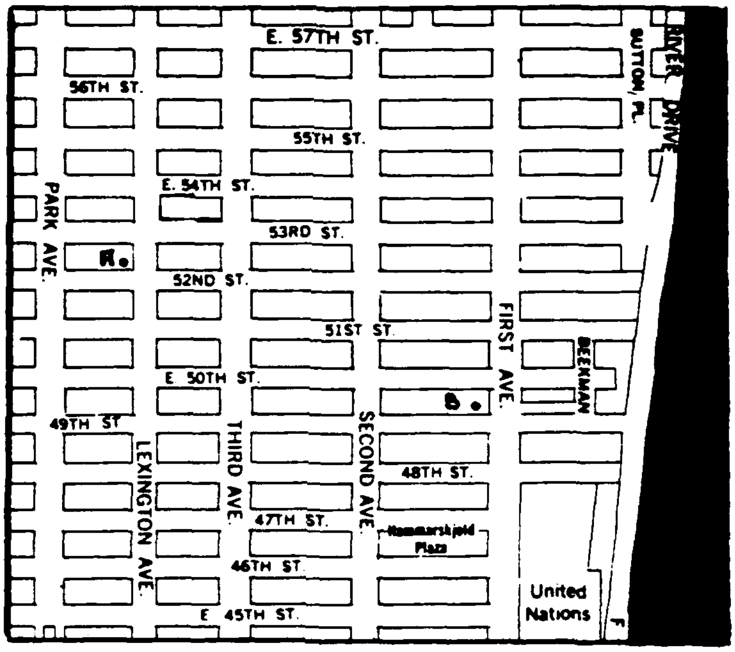
Summing up, the present projet can be seen as a contribution to the study of behavioral variations as such.

1.2. EXPERIMENTAL METHODS

1.2.1. THE MAIN PROCEDURE

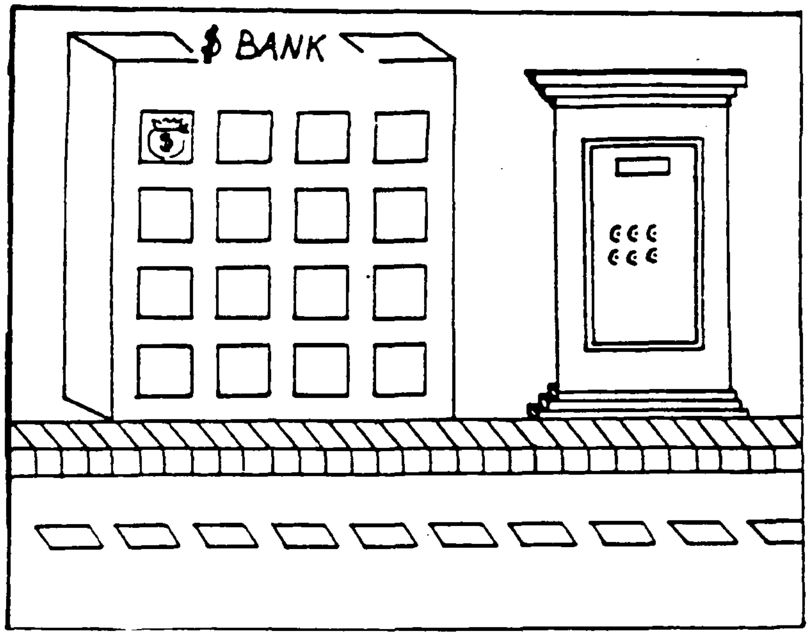
The main technique used in this research is derived from an experimental procedure designed by Vogel and Annau (1973). The technical features will be described at length in chapter 3. It has been modified and elaborated so as to fit the particular aims of the project, and the human subjects which were the main population under study.

The general principle will be easily grasped by resorting to a simple metaphore. Suppose you live in a typical New-World city, where streets and avenues cross regularly at right angles as in the central section of Manhattan (partly represented below). You live at place A, let say close to the corner of Lexington Avenue 52nd Street and you walk daily to your office, located (in B) at the corner of the 1st Avenue 49th Street. So you have to walk three blocks Eastward and three blocks South. There are a number of different ways you can take, all of them equivalent in terms of distance (at least we shall assume so). You might like to use only one of them, and stick to it, day after day, throughtout the twenty years of your professional life in that office. But you might as well change, occasionally, or, so to speak, make a rule of changing. This is typically an open situation, where there are no real constraints on your behavior, but a certain degree of freedom, that you might or might not exploit.



Transferred to the laboratory world, you might think of your spatial daily problem as a maze, with the particularity of offering multiple solutions (there are indeed no blind alley, except that if you do not take the right turns at some critical point you might go off your way and never reach your office).

The subjects in our experiment were not put in a maze, but presented with a two dimensional display that is essentially a visual representation of your Manhattan familiar maze. The video screen, designed below, showed a picture of a four floors bank building, with four windows at each floor. A bag filled with dollars is pictured at the upper left window (4th floor) at the start of a trial. The trial is completed successfully when the subject has brought the bag in the right bottom window on ground floor : the bag is then taken away by a security man and taken to a safe, to the benefit of the subject, who is credited by one point increment on a counter. The whole scene is of course attractively animated.



How can the subject move from the starting point to the end point? Two buttons are available to him : pressing the left or right button, results in the bag moving to the next window to the right or downward respectively. A trial of six presses, three on the left, three on the right button, in any order, is what is needed to obtain the reward. No extra (4th) press is tolerated : it end the trial.

As in the Manhattan example, there are a number (20) of equivalent ways to reach the goal. The apparatus could appropriately be named a visual maze. As it was derived from a cruder version, composed of a 4 by 4 light bulbs matrix, it has been called the MATRIX, and it will be referred to as the Matrix hereafter.

The situation offers a possibility to test :

(1) Whether a subject will use all possible ways, or only a few of them or only one;

(2) Whether he will change his habits, vary more or less as a function of various conditions; for instance, will he be more or less variable according to the fact that his behavior is being rewarded on each successful trial, or only on some of them (intermittent reward or reinforcement);

(3) Whether variability can be induced or increased by differentially rewarding the subject only if he has used the path that is different from the immediately previous trial or from the n preceding trials;

(4) Whether a variability training facilitates the subjects' adaptation to novel conditions;

(5) Whether an individual's characteristics in that situation are correlated with his style in approaching other problems that are used in psychological research, carried out in different, through relevant, theoretical frameworks;

(6) Whether a subject's educational background or socio-cultural status are correlated with his performances.

Other questions have been raised which will be formulated in due time, but need not be mentioned here, since they can be left out without loosing anything substantial in the general approach nor in the main results. Point 5 (above) involves comparisons with other procedures including tasks designed after Piaget, cognitive style tests, etc... These are described in chapter 3.

1.2.2. POPULATION AND EXPERIMENTAL DESIGN

Details on experimental samples are given in chapters 4.2.1., 5.1.2.1. and 5.2.2.1., with the experimental design concerning the two groups of experiments. A few preliminary remark, are in point in order to grasp the developmental (and to some extent comparative) approach of Experiment 1 and the general context of Experiments 2 and 3.

1.2.2.1. Experiment 1

The rationale for the developmental and comparative approach

Experiment 1 deals mainly with the subjects' spontaneous behavioral variability, the possibility to induce behavioral variability and the role of visual feedback in the organization of subjects' behavior. It addresses questions 1 to 5 formulated in section 1.2.1.

Three different conditions were used : in the first one, all correct sequences were reinforced; in the second one, a correct sequence was reinforced if it was different from the 2 previous ones, and in the third one, the visual display did not give any useful information (random displacement of the moneybag).

In this experiment, age groups were compared (5-6 y.o.; 9-10 y.o.; 14-15 y.o. and 18-24 y.o.) and the subjects' behaviors in the Visual Matrix were correlated with their behaviors in several cognitive tasks.

In fact, this experiment is only one part, included in the present project, of a broader developmental study carried out concurrently in our laboratory (Boulanger, 1989). A word of warning is in point here. It might seem unusual to include a developmental dimension in a study that should be of interest to the military. Young adults might seem to provide an adequate and sufficient population. However, we believe that a developmental approach recommends itself if we want to understand how behavioral variability emerges (or, to the

opposite, decays) and how various external conditions, or personal history factors can influence it. A long tradition of scientific psychology, possibly more prominent in Europe than anywhere else, has confirmed the valuable contribution of developmental analysis to our understanding of psychological functions in general and more specifically to our understanding of cognitive functions. The heuristical value of the developmental approach and its explanatory power have been masterfully demonstrated by Piaget's work, but he is only one, admittedly the major one, of a number of great behavior scientists who, on the continent, have emphasized the same point. The names of H. Wallon, whose important work is unfortunately little known out of the French language area, of K. Lorenz, in ethology, not to mention Freud in another aspect of mental life, are only illustrative of a general feature (Piaget's theory has been at the basis of the choice of age-groups considered and of some of the cognitive tasks used in Experiment 1. It will be briefly presented in chapter 2.3.1.).

It should be emphasized that the developmental approach is not just plotting any dependent variable against age, considered as just another independent variable. It is taken to explain, to some important extent, the psychological organization as observed in adult subjects. Development is where we can follow the building up of later functioning, where we can observe significant bifurcations, where we can identify the various elements, such as sensitivity to contingencies, attention, organization in memory, awareness, verbalization, etc. which eventually combine to produce the complex picture found in adult subjects.

A similar reasoning holds for comparative approach in animals. Though animal studies had not been included in the project, except as accessory and as available ressources would permit, and though they have not been in fact included, their importance in dealing with the issue of behavioral variability should not be overlooked. Comparing animal to human performances is crucial in understanding the roots of the process under scrutiny. At the theoretical level, as will be seen in chapter 2.1, it is especially important to validate the hypothesis that the basic process of learning involves the dialectic combination of variation and selection. Demonstrating that animal organisms are, for that matter, generators of variability will of course give foundation to the view that creative behavior obeys the same basic rules as simpler changes occurring in individual animals when they learn. This justifies chapter 2.2.2.1., in which the literature on human and animal studies of behavioral variability is reviewed and discussed. It also justifies that some experiments carried out in the laboratory, concurrently with the present project, by Machado (1988) are reported in a preliminary form, in Appendix 4.

To persuade the reader of the sort of insight that can be provided by animals studies in a problem that, at first sight, might be thought of as specifically human, and of human interest only, let us describe

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briefly one of the simplest experiments that can be and has indeed been performed. Some drugs are sometimes said to enhance learning or cognitive functions - the search for such drugs is indeed the priority in many drug companies today. Some years ago, there were some claims that alcohol and amphetamine were good candidates. A simple measure of learning and supposedly a valid one, in specialized research laboratory, implies recording the time a rat takes to run from the starting box to the goal end of a straight alley. In fact, both drugs had some reducing effet on running time, hence a positive effet on learning. However, Devenport (1983) had the very simple idea of observing her rats in the alley, only to discover that non-drugged rats would go on spending some time fooling around and exploring, while drugged rats would run at maximum speed to the goal. Had they improved, compared to non-drugged rats ? Running time had decreased, true, but exploratory behavior, typical of normal rats - free and able to run just as fast - had been abandoned. Devenport's interpretation, which we think is right, was that not learning had improved but exploratory behavior (which is linked, according to our view, with the concept of variability) had been impaired.

1.2.2.2. Experiments 2 and 3

Experiments 2 and 3 deal mainly with the subjects' spontaneous behavioral variability and the effects of a variability training on the subjects' adaptation to novel conditions.

Subjects were divided in 2 experimental groups. In the first one, after having been reinforced for each correct sequence during 50 trials, subjects received a variability training during 100 trials (they had to produce sequences different from the 2, or from the 10 previous ones, to be reinforced). Finally, they were submitted to a last condition (also 50 trials) where only three particular sequences were reinforced. In the other group, subjects were reinforced for each correct sequence during 150 trials before being submitted to the last condition.

In this second part of our study, variability and performances of adolescents and adults of 18-27 y.o. (militiamen) were analysed as a function of their socio-economical origin and of their types or level of educational background.

There are, to our knowledge, no studies bearing directly on the relations between the subjects' socio-economical origin, their level or their type of educational background, on one hand, and some measure of their behavioral variability on the other hand. However, these variables have been shown to be relevant in some studies of cognitive functioning (some of them will be briefly presented in chapter 2.4. These studies have incited us to included these variables in the study of variability. One could indeed suspect that the educational background is important in favouring or restricting variability. This is a very practical issue since there is now a widespread concern for more "flexibility", "creativity" and the like in all aspects of social and professional life.

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1.3. MAIN RESULTS

A detailled account of results obtained in Experiments 1, 2 and 3 will be given in chapters 4.3., 5.1.3. and 5.2.3.

They can be condensed in the following points :

1. When subjects are presented with a situation where any correct sequence is the only condition for being rewarded (a situation labelled "Normal"), performance improves as the session progresses, while variability decreases. Subjects not only produce fewer incorrect sequences but they also produce fewer different correct sequences.
However, even after a large number of trials under those conditions, subjects never behave in a totally stereotyped manner. They still keep on producing a few different correct sequences.
Subjects' capacity to master the task, - i.e. to improve their performances throughout the sessions - increases as a function of age.
Overall variability - that is variability measured by the number of different, correct and incorrect, sequences produced - is approximately the same in all age groups. But the respective part of the two components changes with age. In younger subjects, it is equally accounted for by the variety in incorrect as well as in correct sequences. As age increases, variability of correct sequences increases while variability of incorrect sequences decreases.

2. In the situation where visual cues no longer coincide with the motor responses, but are given randomly, subjects from 9 years of age and above are strongly disturbed. Their performance is much poorer than when visual cues are consistent with their motor responses. They also show much greater variability of both correct and incorrect sequences. However, they eventually adjust to that situation, all the more easily as they grow older.
On the opposite, younger subjects, 5-6 years old, seem little disturbed by the absence of visual cues. They paradoxically perform better, and in the most stereotyped manner. In fact, they resort, as in other conditions, to a purely motor strategy - such as alternance responses on left and right buttons.
If older subjects eventually use the same motor strategy in that situation - which is indeed the most appropriate in terms of efficiency and minimal error -, they do not use it preferentially when consistent visual cues are provided. In that case, they do not merely produce combinations of motor responses, but they follow various paths to the goal.

3. When the situation so requires, adolescent and adult subjects do adopt more variable behaviors. They even tend to vary more than necessary.

By contrast, increasing variability of correct sequences by differential reinforcement reveals more difficult in 9-10 years old subjects, and still more so in 5-6 years old. The poor performance of the latter in that situation seems related to their difficulty in mastering the matrix operating rules. Using visual informations in order to produce varied correct sequences seems especially difficult to them.
Some results clearly show that, even in adult subjects, the capacity to master the task (as measured by the performance obtained when they are placed in the situation, during the first fifty trials, in which the only condition for reward is to produce one correct sequence) is significantly related to the capacity to adjust later to a situation requiring more variability.

4. When adolescent and adult subjects are confronted with new conditions for reinforcement (namely when three particular sequences only are reinforced), results show that the subjects who have been exposed before to a situation generating stereotypy are able to modify their behavior so that they find the solution. However, they also produce more incorrect sequences and find the solution less quickly than those individuals who have been previously exposed to training of variability.

5. Whatever the age group being considered, there is no relation between the behavior of an individual in the task that has been used here to measure variability on one hand and his performance in the various cognitive tasks which have been used for comparison on the other.

6. Performance in the matrix situation seems to be related to the type of school curriculum but not to the level of studies nor to their socioeconomic origin : subjects who have been trained in so-called technical curricula are slightly less good performers than those who have been submitted to curricula focussed on humanities or social fields. However, this difference is only founded for individuals who have not achieved higher university type degrees.

1.4. CONCLUSIONS

To sum up, the experiments reported here suggest that our approach to behavioral variability bears upon dimensions of behavioral and cognitive processes that are not dealt with by other approaches to the study of intelligence, problem solving, mobility of though, fluidity, and the like which, at first sight, might seem conceptually close to ours. No significant correlation has been found between behavioral variability as assessed by our procedure and relevant measures derived from procedures developed in some of these other approaches. This does not mean that possible links between various approaches are to be discarded, but it is a strong

argument to proceed along the same lines. Data gathered so far are admittedly not sufficient to validate and qualify the general theory eschewed above (and further elaborated upon in the chapter 2.1). they are, however, sufficient to encourage further investigation within this framework.

Empirical results show that behavioral variability, as measured by the specific procedure selected in our experiments, is a property of behavior that can be modulated by various external factors, and that it is, indeed, amenable to the control by its consequences. That is, variability can be induced, or reduced, or increased, by changing the outcomes for a subject of his/her exhibiting variability.

They also show that a subject's performance in such an open situation is, to some extend, predictible from his/her way to react to the initial conditions to which he/she has been exposed. But this effect of initial exposure (a small scale bit of individual history) is itself much variable from one individual to another. Interindividual differences seem to concur with intraindividual variability to maximize (or optimize ?) the range of variations as expressed in a given population.

Contrary to the myth of the potentially creative infant (that we would expect to exhibit a high degree of variability in our procedures, as a high degree of mobility in some of the Piaget's type tasks), behavioral variability increases as a function of age.

Finally, it must be emphasized, again in the limited context of these experiments, that whatever part of the observed variability can be accounted for by identifiable variables, an individual is likely to exhibit a certain degree of variability when there is no pay off for it. This is comparable to this fraction of exploratory behavior preserved in normal rats after they reach an asymptotic level of running time, upon which they are by no means unable to improve.

Though experimenters are usually reluctant to venturing in applications when empirical data are still scarce and obviously demand extensions and replication, a few, admittedly speculative remarks are in point as to practical applications. They are, after all, much less speculative than popularized myths of inborn creativity and of the deleterious action of any educational intervention on the creative potential of humans.

It seems to us counterlogical to think of variability in terms of traits or styles or types. If anything, it is a functional property of cognitive and behavioral processes. As such, it can be influenced by a number of perfectly identifiable variables, and, especially important, it can be increased.

If the role of variability is recognized as the common factor at work from simple motor learning to problem solving and to the

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production of novel behavior, be it in unexpected life situations or in artistic creation, there is no need to oppose the realm of routine, automated, narrowly logical behavior to the realm of spontaneous, imaginative, creative behavior; the domain of rationality and teachability and the domain of unteachable, supposedly creative, irrationality. That man will cope with change, as he will be confronted to it, who will preserve a range of variation, upon accumulated highly trained skills. That man will produce novel pieces of art or science or writing who will keep on exploring potentialities with a background of expertise.

It is hoped that this overview will induce the reader to explore further the theoretical arguments, and the implications of the present approach for the conception of psychology at large, and of what is has to offer to improve educational practices.

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CHAPTER 2

GENERAL THEORETICAL FRAMEWORK

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In this chapter, the experiments that will be reported later in this report are placed in their theoretical perspective.

First, the case is made for variability as an essential aspect of behavior, in the frame of a theoretical approach based on the evolutionary analogy borrowed from biology. Their illustrative studies in the field of problem solving and of animal and human learning are reviewed, and the main experimental procedure used in the present project is described. The importance of the developmental approach, of the socio-cultural factors and of the cognitive-style concept in relation with the specific purpose of this project is discussed, and the experimental techniques selected to include them in our analysis are briefly presented.

2.1. LOOKING AT VARIABILITY IN ITS OWN RIGHT

Variability is not a key-word in the traditional lexicon of psychology. It appears nowhere as chapter head in handbooks, and rarely as index entry. **Variability** is not a psychological function, nor does it refer to a particular context of real life in which psychologists can show their expertise. As it is suggested to take the concept here, it is a property of the material with which psychologists are dealing. The word "material" is used as a neutral term, because a crucial issue is whether **variability** is a more or less inevitable property of the data available to psychologists as they exploit one of their more or less adequate methods of inquiry, or whether it is an intrinsic and possibly functionally adaptive property of the behaving organism. The hypothesis underlying the present approach is that, traditionally, psychologists have been looking at variability as an undesirable property of their scientific data, resulting from the imperfections of their methods and from the peculiar characteristics of their subject matter, but that times are ripe for looking at variability in its own right, i.e. as one important aspect of behaving organisms.

In a first part of this chapter, we shall comment briefly on some of the reasons that, throughout the history of psychology, have encouraged psychologists to deal with variability as something undesirable. Then we shall point to some of the contexts of research where psychologists have been confronted with the problem of variability as a possibly intrinsic property. Finally, we shall suggest links between these various areas of research, that have usually been kept apart, and, at a larger level, links with theoretical and epistemological issues that have emerged in other fields of science in the past few years.

Before that, it is advisable to give our key word simple meaning, leaving for later debate refined distinctions between different meanings that can be given to the term **variability**. **Variability** refers to the property of that which exhibits variations. Technically, variability is assessed by means of probabilistic models, which psychologists have been familiar with for many years.

Since psychology emerged as a science, variability has been considered as an undesirable aspect of collected data, that should be neutralized if it turns out that it cannot be avoided. This reflects the psychologists' obsession to give their field as much scientific dignity as possible. Physics (classical physics) was the model to imitate, both in its elegant measurements and formulae and in its clarifying analysis of causal relations, resulting in a world view in which nothing is left to chance, and where reversibility is the rule, even for those phenomena, such as movements and changes, which only to our human eyes appear to be time-oriented. In such a framework, variability appeared as noise, that any good experimenter should work to get rid of. The epistemological reference to the hard science

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par excellence converged with the legitimate methodological preoccupation for clean experiments : variability, obviously enough, often reflects poor experimental control, and psychologists of the past and of the present are certainly not to be blamed for their efforts towards more rigourous experimental designs and manipulations. But these efforts generally imply that variations are noisy interferences masking lawful relations. If general laws are to be drawn from experiments, variations are to be eliminated or neutralized. This has been one of the major reasons for studying groups, rather than individuals, in the psychological laboratory. When, in some cases, experimenters think they can tolerate variability on the ground that, for all practical purposes, it is not worth spending time and energy in order to reduce it, they simply adopt statistical definition of the events they want to measure, as in sensory thresholds or reaction time experiments.

The concern for constancy and stability has indeed been pervasive in most areas of psychology. For example, much energy has been invested in demonstrating mental tests reliability. The stability through time of the measure provided by the instruments has often being implicitly transferred to the thing being measured, be it intelligence or one of its components, and finally to the individual himself. A deviation from perfect stability has been interpreted as reflecting the imperfection of the instrument (which implies that the subject is stable) or the imperfections of the subject (which implies that he is not really <u>normal</u>). The confusion between statistical norm and psychological norm has been a persistent problen in psychology, as it is well-known; deviation from the central tendency (the word <u>deviation</u> itself is loaded with connotations of normativity) has been interpreted as deviation from psychological normality. Similar efforts have been made, in personality research, at indentifying stable personality characteristics and traits, altogether permanent throughout an individual's lifetime and structually consistent at any given moment. Various brands of typologies offer illustrations of that trend.

By taking this stand, psychologists have simply shared with many scientists and philosophers a certain view of the place of **chance** in the universe. This view, as it is the case for most basic ideas in scientific explanation, goes back to ancient thinkers, such as Hippocrates for whom "chance, when you look closely at it, turns out to be nothing. All what happens has a cause, which in turns has a cause that produces it .One cannot figure out that chance could exist in nature : it is only a name ". In a modern version of this view, chance is seen as "the measure of our ignorance" after Poincaré's word. It has of course, as already pointed to, been consolidated by the very successes of classical physics in its quest for a description of the world in which nothing would be left undetermined.

However, there has been, for long, another way to think of **chance** in nature. Following Aristotle, it contends that chance has its place in its own right in explaining reality. Probabilistic accounts, or randomness proper are not necessarily the disguise of our ignorances : they eventually reflect the nature of things proper.

The conflict between these two opposite views has dominated, as is well known, the history of modern physics. In their recent book Entre le Temps et l'Eternité (1988) - no less relevant to our issue than their earlier work La Nouvelle Alliance (1979) - Prigogine and Stengers show how Boltzmann, confronted with the problem of irreversibility in thermodynamic systems, "forced to choose between opening physics to temporality and remaining faithful to the principles of dynamics the constraints of which he was experiencing, made the choice of fidelity. To the dynamic (*that is integrating the concept of irreversibility -our comment)* interpretation of the second principle (*of thermodynamics)*, he subsituted a **probabilistic interpretation**". This interpretation accounts for the irreversibility that we observe in terms of the crude, "macroscopic" character of our observations : were the observer equipped with better tools, he would be in a position to follow each individual molecule, rather than populations, and would describe a reversible system, in conformity with traditional principles. Boltzmann was forced to this interpretation counter to his own intuition.

No wonder that psychologists, fascinated as they were by the model of traditional physics, have been slow in facing the problem of variability.

They have, however, been repeatedly confronted with phenomena that could not be accounted for in the traditional way. Change of behavior as the result of learning is a case in point, though this has often been overlooked, as we shall see in a moment. The problem is even more crucial, of course, when one comes to problem solving, whenever new solutions must be found for an organism to adjust to a new situation, or when one comes to that category of novel behavior that we call creative. It has been faced also in the field of developmental psychology, where the idea of mere unfolding of prebuilt potentialities has been abandoned long ago, and in the field of ethology, where instinctive behavior has been shown to exhibit a much wider range of adaptability than had been thought before.

The study of exploratory behavior, of play in (satiated) animals and humans has raised similar questions in another context. The functions of play are manifold - including preliminary exercice of a developing capacity, the maintaining of a certain level of activity even when the environment is not very stimulating, the collect of information that can be used later, etc... But many forms of exploratory and play behavior seem to have one important ingredient in common : the production of a range of behaviors that do not have

an immediate adaptive value, but do certainly contribute to adaptation in the long run.

Clinical psychologists, in their own field, were never very happy with the traditional accounts of experimenters : individuals 'history contain events, bifurcations, singularities that general laws do not seem to explain very satisfactorily.

In spite of all these and other empirical situations, psychologists have resisted to considering variability and variations as an intrinsic property of their subject matter.

This is all the more surprizing since the key explanatory concepts had been offered for some time by biology, in the framework of evolutionary theory. A number of psycholog'sts have, of course, been aware of the possibility to approach their own problems with that valuable tool. To quote only a few of the most famous of those, an evolutionary account of learning or of intelligence has been proposed in classical papers by Tolman (1925, 1932), Campbell (1974), etc . But it did not follow that research in these areas developed extensively, with emphasis on the study of variations as playing a central role in behavioral changes and noveities.

We shall discuss here at some length the case of Skinner and of the part of the field of learning that is linked with his name (for a more detailled discussion, however see Richelle, 1987).

In several of his recent theoretical papers, Skinner has explicitly and repeatedly exposed his view of the learning process as involving essentially the same sort of mechanism as biological evolution, namely a combination of variation and selective pressure (Skinner,1966, 1981, 1985). The latter is exerted in individual learning by the action of the reinforcement, that Skinner defines as a selective action. This view had already been expressed as early as 1953 in his book Science and human Behavior, and it was, indeed, already in germ in his early thirties theoretical papers. This would have suggested, at least from the mid fifties or so, to experimenters in that particular field, - that revealed quite prosperous in those days - systematic attention to the nature and the sources of variations, that were assumed to provide the raw material upon which the selective action of the reinforcer could operate.

According to this hypothesis, there should be, in individual learning, some sources of variation equivalent to biological variations due to mutagenic processes and to the recombination of genetic material by sexual reproduction within populations. But the sources, the nature and the role of behavioral variations were to be documented if the evolutionary analogy was to gain some heuristic and explanatory value at the level of ontogeny. Curiously enough, with very few casual exceptions that went unnoticed, practically none of Skinner's followers engaged in that sort of enquiry until the

seminal paper by Staddon and Simmelhag (1971) and a few other theoretical contributions about the same time (Segal, 1972). Still then, much more attention continued to be devoted to the selective action of the environment (under the concept of *contingencies of reinforcement* familiar to operant conditioners) than to the sources of variation; much more attention has been given to the study of *steady states* - that is to say the maintenance of behavior acquired earlier - than to the dynamic phase of learning, in which the role of behavioral variations was more likely to appear. This has consolidated the idea, that has eventually been adopted by many psychologists in other fields as well as by the laymen, that conditioning is a process of stereotyped repetition of simple motor behaviors, that it has little to do with more complex adaptive behavior, and that it certainly has no link whatsoever with problem solving, not to speak of creativity. This has resulted in a most curious dissociation between the current picture of a basic behavioral mechanism - and indeed the bunch of empirical data accumulated in the laboratory - and the main theoretical tenets, which, in Skinner's mind, offered unified treatment of individually adapted behavior, from the apparently simple forms observed in animals up to the most elaborate conducts of creative humans (Skinner, 1970, 1971). As it were, only one half of the learning process has been seriously explored during the fifty years or so of research in the Skinnerian tradition.

The situation is, in some way, quite comparable to Boltzmann's difficulty in going beyond the traditional paradigm, in spite of his own intuition to the contrary. It is worth mentioning at this point, as pointed out by Prigogine and Stengers, that Boltzmann's repressed intuition had been essentially inspired by Darwinian thinking, - as later Prigogine's approach itself, that led him to the discovery of dissipative structures and to his recent reformulation of the place of time in physics.

It is fair at this point to mention the existence of a few experimental studies on the specific issue of behavioral variability in learning processes. Some are closely linked with an interest, that developed in the seventies, for the stream of behavior that takes place besides the conditioned responses that are being controlled and recorded - an interest mainly derived from the encounter with ethology and with the species-specific constraints on learning mechanims. Other experiments have been explicitly designed to study variability of conditioned responses, - coming back to an early Skinnerian concept defining the operant as a *class* of responses, within which there is freedom to vary from intance to instance -. Such experiments are aimed at describing conditions that favor or restrict variability, and at exploring the possibility to use variability as the critical dimension of behavior upon which the reinforcement will be contingent. In other words, can variability be selected as an

adaptive device ? These studies have a direct relation with the present project and will be reviewed below in this chapter (see 2.2.2.1.).

The heuristic value of the evolutionary analogy in psychology has also been recognized by other major theorists, whose work has shaped XXth century psychology. Lorenz has played a central role in putting the study of animal behavior in evolutionary perspective, and he has given, in his later works, extensive treatment to the concept of variation in relation with individual learning mechanisms. The notion of *open vs closed programmes for learning* opposes species exhibiting high behavioral variability, and consequently high capacity for learning, as a consequence of having evolved in a changing environment, and species that, to the contrary, because they have evolved in a homogeneous environment, are equipped with very limited though very efficient behavior patterns, with little place for flexible adjustment to unusual conditions. For instance, horses, or jelly-fishes, which have evolved in a highly homogeneous environment, have developed behaviors that are finely tuned and very effective in that stable ecological niche. Rats, and humans have been evolving in most various evironments in which individual styles of adjustment are essential for survival.

Piaget has, of course, throughout his monumental work, continuously resorted to evolutionary thinking. His search for *continuity from elementary forms of biological processes* and the most complex achievements of the human mind in logics and science makes him probably the most biologically oriented psychologist in our century. Richelle (1976) has argued elsewhere that, in spite of important differences, Piaget and Skinner have in common some basic views with respect to the evolutionay analogy and to the role of variations (cf Piaget's concept of *desequilibrium*) in the dynamics of behavior. Though their experimental work can be criticized on the basis of more carefully collected data, and though some aspects of their theoretical formulation need revision in the light of recent advances, it seems highly significant that, having started on so different paths, they eventually leave us with very similar questions opened for further research.

To these three major theoretical contributions, one could add a number of possibly less ambitious or less prestigious, though no less significant works. We shall not undertake to enumerate them all here. Suffice it to give a few examples, already alluded to. The study of exploratory behavior, including the pharmacological and the neurophysiological aspects, has offered many confirmations of intrinsic variability (see, among others, the work of Devenport). In a completely different area, the case of differential psychology deserves special attention. Differential psychology deals with **interindividual** variations, contrary to various fields of research

mentioned up to now, which deal with **intraindividual** variations, as does also the present piece of research. But interindividual variations are of no less interest in biological thinking than intraindividual variations : variability within a population, that is between individuals, is an essential factor in the dynamics of evolution. In psychology, interindividual variations have been looked at in exactly the same way as intraindividual variations. They have been treated as unfortunate and uninteresting deviations from the norm, or central tendency of a population, as divergences that go counter the strict lawfulness of nature. Differential psychologists have been keeping themselves busy at identifying the factors accounting for these deviations, mainly because they cannot be ignored for practical purposes - if people are different, you have to take these differences into account when they are to be put in a school or in a job - but these remain essentially minor violations to basic similarity. And differential psychology has been seen as a minor field, imposed, so to speak, by daily like practical constraints, though with little bearing on a general and deep understanding of behavior and mind. Significantly enough, differential psychology had no place of it own in the well known handbook of experimental psychology that was used as the reference work by French speaking psychologists for the last 25 years (Fraisse and Piaget, 1963); it was devoted a full section of the comparable reference book in applied psychology (Piéron, 1960).

No doubt that this peculiar status of differential psychology was to some extent influenced by the popular ideology of equality of men. Many psychologists failed to make the important distinction between the ethical concept of **equality** and the empirical fact of **diversity**. Psychological differences were looked at blemishes, with the consequence that the productive aspect of variations were lost in the process.

A change of perspective has emerged, however, in the last few years. Some differential psychologists have turned to a radically different view of their own field. Interindividual variations are analysed as reflecting the richness of adaptative potential at the level of a population. This approach has been applied to cognitive development and problem-solving. Various strategies observed in different individuals confronted with a problem situation are seen as offering a range of alternatives, each of which have its heuristic value, especially if the context of changes. The obsession for rank ordering various strategies hierarchically is abandoned. (For an example of this new approach to differential psychology, see Lautrey, 1988).

To sum up, we see converging, from very different alleys, ideas and facts that confirm the hypothesis that behaving organisms are to some extent "generators of variability", because selection upon variations is the general unifying mechanism at work in the

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production of novelty in the living world, be it at the level of phylogeny, at the level of individual learning (not to be conceived of outside the species population anyhow) or, as has been suggested by several schools of thought in cultural anthropology, at the level of cultural history.

Before we focus on aspects of the issue more specifically relevant to the present project, it is appropriate to broaden our scope for a while, and to point to the fact that conc- - - r variability, and more generally for a variation/selection accou: of changes, is not limited today to a few psychologists - in add...on to the professional biologists traditionally working along Darwinian lines. A similar trend can be observed in a number of other areas of research.

An evolutionary approach to the problem of science development had already been adopted years ago by Popper (Obje c ive Knowledge. An evolutionary approach, 1972).

In his introduction to the French edition (1978) of The lc gic of Scientific Discovery, Jacques Monod rightly pointed out : "Conjecture and refutation play in the development of knowledge the same logical role (as sources of information) as mutation and selection, respectively, in the evolution of the living world. And if natural selection has, in the living world, been able to build the mammals' eye or the brain of Homo sapiens, why would selection of ideas not have been able, in its own realm, to build the Darwinian theory or Einstein's theory ?"

Especially relevant to our argument is Popper's characterization of the growth of knowledge as a special case of learning : "The growth of knowledge - or the learning process (italic ours) - is not a repetitive or a cumulative process but one of error - elimination. It is Darwinian selection, rather than Lamarckian instruction".(Objective knowledge, p. 144) "All this may be expressed by saying that the growth of our knowledge is the result of a process closely ressembling what Darwin called "Natural selection"; that is the natural selection of hypotheses : our knowledge consists, at every moment, of those hypotheses which have shown their (comparative) fitness by surviving so far in their struggle for existence; a comparative struggle which eliminates those hypotheses which are unfit". (Ibid, p. 261).

Popper goes on by framing this view of the evolution of scientific knowledge in the general view of the development of knowledge - or learning - in living systems : "This interpretation may be applied to animal knowledge, pre-scientific knowledge, and to scientific knowledge." He further insists on the status of the analogy : "This statement of the situation is meant to describe how knowledge really grows. It is not meant metaphorically, though of course it makes use of metaphores... From the amoeba to Einstein, the growth of knowledge is always the same ...." (Ibid, p. 261)

In a field quite close to psychology, neurobiology, major recent theoretical advances are centered on similar concepts. After Changeux 's theory of "selective stabilisation", that unfortunately missed a real encounter with current relevant research in psychology, the recent book by Edelman (1987) Neural Darwinism. The theory of neuronal group selection, will certainly appear as a decisive breakthrough, as well as a unique source of inspiration for psychologists involved in research on variability. This book would deserve a thorough discussion, that would extent far beyond our present concern here, not only as to its central propositions for neuronal mechanisms underlying learning, but also as to its general questioning of the current information processing paradigm. that dominates today cognitive psychology, and, as many psychologists believe, psychology at large. We shall only make two short quotations from Edelman's conclusion chapter, that perfectly fit in the general scheme of this theoretical introduction.

"It is important, for example, to distinguish between evolutionarily determined behavioral responses and those dependent upon individual variation in somatic time within a species. In somatic time, the first view implies instruction - information from the environment *fundamentally* determines the order of functional connectivity (although not necessarily that of physical connectivity) in the nervous system. The second alternative is selection - groups in preexisting neuronal repertoires that form populations determined by phylogeny and ontogenetic generators of diversity are *selected* by stimuli to yield highly individual response patterns."

Edelman proposes a neuronal theory that integrates the developmental dimension and the requirements assigned by the study of behavior both in ethology and in experimental studies of learning mechanisms (the synthesis suggested above between Piaget, Skinner and Lorenz), and, though resisting the temptation to venture into generalizations to cultural evolution, he envisions the reconciling between the lawfulness of nature and the individual creation of novelty :

"If extension to such issues finally turned out to be feasible, then it would not be surprising if, to some extent, every perception were considered to be an act of creation and every memory an act of imagination. The individualistic flavor and the extraordinary richness of selective repertoires suggest that, in each brain, epigenetic elements play major and unpredictable roles. Categorical genetic determinism has no place in such systems; neither has instructionist empiricism. Instead, genetic and developmental factors interact to yield systems of remarkable complexity capable of an equally remarkable degree of freedom. The constraints placed on this freedom by chronology and by the limits of repertoires, while definite, do not seem as impressive as the unending ability of somatic selective systems such as the brain to confront novelty, to generalize

upon it, and to adapt in unforeseen fashions."

Finally, we should draw attention to the challenges faced by psychologists in the field of A.I. The main ambition for the near future is to build, if this eventually reveals possible at all, machines endowed with a capacity for learning from their previous behavior, not only in terms of increased memory storage, but of improved adaptation to unexpected problems, and, one step farther, creative machines There are some hints that adequate models to produce such "automata" (maybe the word is inappropriate to name a novelty producing device) will imply some variability generating system, and will be designed after the evolutionary analogy, that will have proven successful to account for changes and the emergence of new forms at all level of the living world, and to inspire man-made artifical man-like robbots.

2.2. BEHAVIORAL VARIABILITY IN PROBLEM-SOLVING AND LEARNING PROCESSES

In this chapter, selected studies in the field of problem-solving, and in the field of learning will be reviewed within the general theoretical framework outlined in the preceding section. Other domains mentioned and briefly discussed in the preeceding section will be left out, because, though theoretically no less important, they are less relevant to the research that will be reported in the next chapters.

2.2.1. BEHAVIORAL VARIABILITY, PROBLEM-SOLVING AND CREATIVITY - A SELECTED REVIEW

Problem-solving is a major topic in research on human intelligence. Studies of problem-solving have developed in various directions, using various methods adapted to various levels of complexity, but the phenomena addressed to share basic common traits. A problem is always a situation that is novel, in some respect, for the subject, so that he does not have in his repertoire the particular behavior at hand, that would provide the solution. Experiments on problem-solving, however, have often emphasized problems designed after problems already familiar to the subjects and/or having only one solution. They also, quite often, focus on the solution proposed rather than on the ways used by subjects to find it out. Studies of that kind are not relevant to our concern.

Some researchers, however, have been more specifically interested in observing how subjects perform in very unusual situations and in the successive steps they take towards a solution. To that end, they have designed situations, typically characterized by their novelty, providing for observation of procedures used by the subject, and allowing for several (equivalent or non equivalent) solutions. Some of these studies are reviewed hereafter.

In a first type of situations, subjects (usually human adults) are faced with a complex goal : they have to solve a practical problem by using one or several common objects, which have a specific function in daily life, in a novel, totally unusual way.

The "candle" problem designed by Duncker (1945) is a classical example. Subjects are instructed to mount a candle on a wall. Available to them are cardboard match and thumbtack boxes, matches and thumbtacks. The problem can be solved by tacking an emptied box to the wall and placing the candle in or on it.

The "two ropes problem" of Maïer (1930) is an other example of the same type. In this problem, two ropes are attached to the ceiling and subjects are instructed to join the two ropes. However, the spacing between the two ropes does not enable the subject to seize one rope while holding the other. The problem can be solved by giving an oscillatory movement to one of the two ropes. Different objects are available (such as electric relays) that can be used as weight to transform the rope in a "pendulum". Such situations seem appropriate to investigate what has been called the "functional fixity" of subjects, who stick at the usual way to look at objects and, consequently, are prevented from finding out a solution.

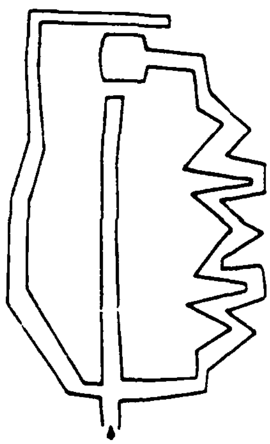
A main result of these studies is that it is possible to increase or to decrease the subjects' difficulties in solving the problems by manipulating the functional value of objects. For example, in the "candle problem", the fact to present the box full of thumbtacks, rather than empty, increases the subjects' difficulty in using the box as a support for the candle (Adamson, 1952) (this effect is still increased when a high motivation level is induced in the subject (Glucksberg, 1962). In the "two ropes problem", if subjects are first invited to use an object in its usual way (f.i. the electric relay to complete an electric circuit), they experience more difficulties in using it later for a different function (as the weight of the pendulum) (Adamson and Taylor, 1954).

On the contrary, if subjects are first trained to consider unusual utilizations of available objects, their performance improves.

The global effect of several types of incentives (e.g. : "be active" (Adamson, 1952)) or hints (e.g. : the experimenter guides the subject to the solution by insisting on some elements (Maïer, 1931)) has also been analysed.

The exploitation of such situations is, however, limited by the fact that few subjects find the solution. Moreover, evaluation of performances is complex and the analysis of all variables involved is, as one might say, impossible (subjects can only be compared with regard to the number of trials and to the time necessary to reach the goal, two measures which leave out most relevant informations as to their strategies).

Another type of problems provides for systematic study of the subjects' capacity to change their method during the course of the experiment. Some of these problems are less complex that those described above and can be proposed to children as well. Here, the work of Luchins (1942) is a classic reference. He showed his subjects (adults and children) several printed mazes (see example below) and asked them to find the correct itinerary and to map it out with a pencil. In these successive mazes, the correct itinerary was always the same; it was called "training itinerary" : T (to turn to the right just after the entry and next to go a long way round before reaching the goal). Then, he proposed a maze with a similar aspect but in which a second itinerary is possible that directly connects the entry to the goal. This last one was called "direct itinerary" : D.



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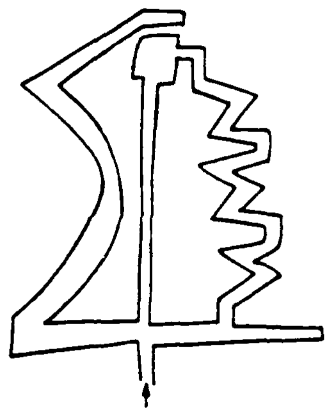

D MAZE

In all age groups, the great majority of subjects continued to follow the indirect itinerary (T). Luchins called this phenomenon "psychical blindness". A similar concept, "mental rigidity", was proposed by Oleron (1955). The effects of several variables (environmental, cognitive and motivational) on this phenomenon have been analysed. Cowen (1952) showed that "psychical blindness" is increased in a stress situation. The effect of "psychical blindness" has been confirmed with mathematical problem-solving ("jar-problems", Luchins, 1942), the discovery of words hidden in sets of letters (Luchins, 1942; Maltzman, Fox and Morrisett, 1953), or the change of the orientation in block design tasks (Botson and Deliège, 1976).

However, as already noted by Luchins himself, it must be emphasized that, in all age groups, some subjects are not affected by the "psychical blindness" effect.

Relevant to this last point, observations by Kaufmann (1979) using a modified version of the Luchins' jar-problems, showed that some subjects spontaneously change their method of solution. On the contrary, other subjects always use the same method, even if easier methods are possible. Kaufmann suggested that these two types of subjects can be characterized by two different cognitive styles : respectively, the "Explorer" and the "Assimilator" styles. Kaufmann's study is original in that it takes into account the spontaneous behavior exhibited by the subjects, no particular solution being induced. Though the type of problems designed by Luchins provide clear-cut results, in terms of global performance, and of effects of some variables, they do not give much informations as to the processes involved.

Harlow's concept of "learning set" (Harlow, 1949) is, obviously, close to the issues discussed above. Harlow explicitly asked the question : "What are the types of learning which induce a more or less rigid attitude in the adaptation to a new situation ?" The tasks he used were simple discrimination tasks and the experimental conditions were well controlled. In Harlow's experiment, subjects - children and monkeys - were submitted to series of visual discrimination problems. Successive pairs of objects were presented and the subject was to choose one of the objects according to a particular characteristic that would be changed from one series to another. In the last series, subjects were able to produced a correct response after only one trial.

Subjects had been developing a learning set, after Harlow's words, they had been learning to learn so that they would be able, progressively, to arrive at an immediate solution to new problems (new, though of a typically similar structure). What is enhanced by developing learning sets is the general capacity to adapt to new problems.

A number of experiments based on the learning set concept have explored the conditions favouring flexibility (Buss, 1953; Harlow, 1949; Schroder and Rotter, 1952). As a rule, they show that multiple learning (e.g., involving in each successive series, a different modality of a same criterion or a change of criterion from one series to the next) increases flexibility. The role of reinforcement has also been investigated. Buss (1952, 1953) has found that continuous reinforcement in a learning set procedure increases the rigidity in the test-problems and, conversely, that intermittent reinforcement increases flexibility.

These studies on "learning sets" involve very simple learning which do not seem to have a direct relation with the usual problem-solving situations. Their merit, however, has been to approach the problem of behavioral flexibility in a simple rigorously controlled situation, providing for easy measurement of crucial variables. In that respect, experiments carried out after Harlow's model meet the requirements made explicit by several authors

(Oléron, 1955; Richelle and Botson, 1974), stating that notions such as rigidity or flexibility will take a precise meaning, only when they will refer to objectively measured behaviors. Using simple behaviors in easily controlled conditions is "one of the best ways to prevent the notion of rigidity from being lost in abstractness and remain close to metaphysical concepts" (Oleron, 1955, p. 89).

In the field of creativity, various studies have been carried out with the goal of increasing the subjects' capacity to vary their behaviors in an original way. Some of these studies have shown that it is possible to build upon the spontaneous variability of an individual in order to enrich his behavioral repertoire. A most typical experiment has been done by Pryor, Haag and O'Reilly (1969) on sea purpoises. They succeeded in training these animals to emit increasingly variable behaviors by reinforcing new behaviors as they were emitted. "New" was defined, in that case, by reference to the set of behaviors previously produced in the session. Subjects eventually produced motor behaviors that had not been observed yet in the species, though described in neighbour species. Botson and Deliège (1976) have used a similar procedure with very young children and have obtained similar results. However, they have met the same difficulties as Pryor et al : the multiplicity of behaviors makes the situation so complex that the observers' memory span cannot keep up with the subjects' variability; and identify novel behaviors to be reinforced.

Goetz and Baer (1973) have avoided this problem by requesting 4 year-old children to build any structure with wooden blocks. They systematically reinforced any new block design; children did indeed produce a wide range of new arrangments. They also observed that this type of learning may be transfered to very similar tasks but not to different ones (e.g., the reinforcement of new forms of painting has no effect on the production of new forms of building : Holman, Goetz and Baer, 1977).

Richelle and Botson (1974) choose to consider flexibility in a functional perspective of problems solving and to avoid the development of flexibility only for itself, on the ground that an increase in behavioral flexibility out of context and without a goal would be void of meaning, and of no help to people when faced with unexpected problems. In a series of experiments, they trained 5 year-old children to solve practical problems by using materials in unusual ways, by destructuring and recombining objects and pieces of objects. That training induced flexibility of behaviors that was not observed among subjects of a control group. Furthermore, this capacity can be transfered to somewhat different tasks used as post-tests. The procedure was inspired by the progressive and errorless approach to training that is often viewed as appropriate only in those motor training involving high risks (like car-driving or aircraft piloting). The situation was organized in such a way as to

first let the subjects produce a succession of small and simple behavioral units from his familiar repertoire. Then, difficulties were progressively increased. The experimenters arranged the contingencies so that each successive behavior would be adequate and therefore reinforced by approval. This refined procedure has various advantages : it makes it possible to identify difficulties linked to behavioral modifications during learning and difficulties related to the transfer to different situations.

Botson and Deliège (1976) have attempted to describe more precisely the main processes involved in the sort of training proposed by Richelle and Botson and to identify those behavioral changes that seem crucial in solving the problems to which subjects were confronted. They have systematically analysed two types of behaviors : (1) classification behaviors : the subject is asked to organize a set of elements (objects displayed before him/her) in any way he/she wishes to do. After his/her first arrangment, he/she is asked to carry out another classification and so on ("cognitive change"); (2) "handling" behaviors : the subject has to change the orientation of similar wooden blocks in order to embed them in holes of different shapes ("handling change"). These two types of behavior change can be seen as different types of elementary "changes", which are necessary if a large number of different solutions to a given problem are to be discovered. Botson and Deliège have studied the evolution of these two "elementary aptitudes for change" as a function of age, from the age of 4 years to 12 years. Results have shown that the evolution is parallel for the two types of "change" : performances, as well as the capacity to make use of hints given by the experimenter, improve as a function of age. There is also an increase in the perseverance in searching for the solution to a problem.

We shall not describe in further details the numerous experiments reported by Richelle and Botson (1974), Botson and Deliège (1976) and Deliège et al. (1982). Suffice it to capture their main conclusions, that are relevant to our purpose. What they have observed does not support a common opinion according to which behavioral flexibility, variability or creativity - however one likes to name it - is decreasing as a child grows older. On the contrary, such capacity seems to be the results of a slow construction. Initially, the child would tend to repeat the same type of solution (stereotypy or perseveration) and would only progressively change his behaviors when it does not work. Their results also showed that subjects can be trained to change their behavior or their "attitude" if appropriate procedures are put to work. These procedures may, paradoxically, be highly structured and controlled. For instance, in one of these experiments, subjects were presented with a wide variety of objects on which they would apply one type of action, say <u>pull</u> or <u>push</u>. Objects were initially of a kind that normally induces that particular action -say press-buttons for push -, but progressively they were of a

kind to which pushing does not usually apply. Experiencing many situations of this type, subjects would eventually exhibit a quite generalized tendency to act in unusual ways, in order to solve a given problem. They have, in some way, developed a "learning set" of a particular kind.

These studies offer a good, though simple illustration of the continuity assumed to exist between creative behaviors and other more elementary forms of behavioral changes.

If this continuity hypothesis holds, it should be possible to look at apparently most simple forms of learning as involving basically the same kind of process as creative behavior displayed in art, literature or science, or, at a more modest level, in efficient solving of unusual problems that can be encountered in daily life.

In the next section, some studies on variability in the context of simple learning - namely operant conditioning in standard situations - will be reviewed along the lines followed in the preceding section.

2.2.2. BEHAVIORAL VARIABILITY AND OPERANT CONDITIONING

2.2.2.1. A selected review

Studies to be reviewed here concern humans as well as animals. (More details on animal studies, however, can be found in Boulanger et al. (1987)). They are organized around two main axes :

(1) the influence of various factors on spontaneous variability of the operant response.

Spontaneous variability refers here to variations that are exhibited in some dimensions of a given response (f.i. its duration, its location, its strength, its structure, and so on) in spite of the fact that such variations are not required, that is, they are not a condition for reinforcement;

(2) the effect of selectively reinforcing the variability of the operant response.

Here, variability is assumed to be a property of behavior amenable to the selective action of the consequences. As responses of a given duration or location can be shaped by reinforcing these properties selectively, so responses characterized by their variability can be rewarded in such way as to maintain or increase variability.

Operant responses are either simple responses or complex responses, i.e. sequences of simple responses. These complex responses bring us closer to situations classically described as problem-solving tasks.

2.2.2.1.1. Spontaneous variability

2.2.2.1.1.1. Simple operant responses

Antonitis (1951) is to be credited for one of the earliest studies on the variability of operant responses. In his experiment, location was the critical dimension of the response, the variations of which were under scrutiny. The rat was to put its nose at any place along a horizontal split 50 cm long. No particular location was required for the response to be reinforced. When rats were exposed to a continuous reinforcement schedule (CRF), in which each response is followed by a food reward, variability of response location progressively decreased. The variability increased in extinction or in intermittent reinforcement schedules. Eckerman and Lanson (1969) have confirmed Antonitis' results in a similar procedure with pigeons. Since then, the same effects have been observed on other dimensions of the response like its duration (Crow, 1978; Lachter and Gorey, 1982; Millenson, Hurwitz and Nixon, 1961), its intensity (Notterman, 1959), its latency (Stebbins, 1962) and its amplitude - measured by the displacement of a lever - (Herrick, 1963, 1964, 1965; Herrick and Bromberger, 1965).

As a rule, when the criterion defining the operant class does not put much constraint on the range of variations, initial variability (i.e. the whole range of authorized variations is used) eventually gives place to stabilization around a preferred value. This increased stereotypy under exposure to continuous reinforcement, reflects the control by the reinforcement and can be explained by the law of least effort (Herrick and Bromberger, 1965), or in terms of optimalization of behavior (e.g., Notterman, 1959; Staddon, 1980).

Several authors have observed an increase in variability in intermittent reinforcement schedules (following exposure to continuous reinforcement) (Eckerman and Lanson, 1969; Ferraro and Branch, 1968; Herrick and Bromberger, 1965; Lachter and Gorey, 1982; Millenson and Hurwitz, 1961; Tremont, 1984). However, contradictory results suggest that various factors, besides intermittence of reinforcement proper, can influence response variability in such schedules (Boren, Moersbaecher and Whyte, 1978; Herrnstein, 1961; Millenson, Hurwitz and Nixon, 1961). In some cases, other behaviors interact with operant responses and can modify the expression of its variability. This "behavioral context" effect seems to be related to the particular dimension of the response being considered (e.g., the strength of the response is less influenced than inter-responses intervals). Intermittent reinforcement schedules involving a temporal component, such as Fixed Interval schedules induce an increase in variability. Results obtained with so-called ratio schedules (in which a fixed or an average number of responses are required for reinforcement), are inconsistent.

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In children, using a device with several responses available, Mc Cray and Harper (1962) have obtained a decrease of the variability of the response location in continuous reinforcement and an increase under intermittent reinforcement schedules and under extinction.

2.2.2.1.1.2. Complex responses

Situations were the reward is contingent upon correct sequences of simple motor responses, come closer to what is classically described as problem- solving tasks.

Vogel and Annau (1973) have elaborated such a task for pigeons. The device includes a 4 x 4 light bulbs matrix, two response keys and a grain dispenser. The procedure is a discrete trial procedure. At the start of the trial, the upper-left bulb is lit. The trial is completed when the bottom right bulb is on. Only one bulb is on at a time. The way to complete a trial is to switch the light step by step, downward and rightward, by operating the two response keys, a key A response producing a move one step to the right and a key B response one step, downward. Three responses on each key, in any order, are enough to complete a correct, reinforced trial. Any extra (4th) response on one key (moving the light virtually out of the matrix) stops the trial. There are 20 equally correct ways, and 30 possible incorrect (ending with a 4th response on one of the keys) sequences.

The same task has been used by Perikel (1982) with rats. It has been used by Schwartz (1980, 1981a) with pigeons in a slightly modified form (5 x 5 light bulbs matrix instead of 4 x 4). In each case, a high decrease of sequences variability with emergence of a dominant sequence (which appears in the majority of trials) is observed when all correct trials are reinforced. The sequences variability increases under extinction, except in pigeons which have received an intensive training prior to extinction (50 sessions of 50 trials instead of 20 sessions) (Schwartz, 1980, 1981a).

These results suggest that the learned patterns of responses become functionallly integrated. That is, the complex sequence becomes a behavior unit in itself, rather than a combination of independent simple response units; and it is little influenced by environmental changes.

Data from other experiments support this hypothesis :

- interrupting the training sessions for 60 days does not influence the performance or the variability of the sequences when the pigeons are replaced in the training situation (Schwartz and Reilly, 1985).

- for pretrained pigeons, a modification of the light cues ("light-off" matrix or random displacement of visual cues) only temporarily alters the performance, and the dominant sequence,

developed during pretraining, rapidly reappears (Schwartz, 1981b);

- pretrained pigeons placed in a Fixed Interval Schedule (FI) or in a Fixed Ratio Schedule (FR) do not increase the variability of their sequences (Schwartz, 1982b). These schedules only modify the latency (i.e., time between the beginning of a trial and the first peck of the sequence). They have no effect on the time separating pecks within the sequence.

- if one considers the sequences as individual responses, the behaviors of pretrained pigeons which are submitted to multiple or concurrent schedules of reinforcement, are similar to those observed in studies on simple responses (Schwartz, 1986).

At first sight, these results seem to confirm that a sequence is not really a complex sequence composed of independent pecks, but that it forms an organized unit.

Parallel experiments have been carried out with human adults. Using a 5 x 5 matrix, Schwartz (1982c) has shown that human subjects also adopt a stereotyped behavior when they are reinforced for 50 % of their correct sequences and that the variability of their sequences increases in extinction. If only one subclass of all possible sequences is reinforced, subjects develop stereotyped sequences that belong to that subclass. Moreover, Schwartz has noted that after a pretraining, subjects have difficulties to abstract the functioning rule (all combinations of 4 pushes on each response-button are correct) and that they express themselves in terms of light displacements (road to follow). Boulanger (1983), using a 4 x 4 matrix, has also observed an increase of sequence stereotypy when each correct sequence is reinforced. Pretrained subjects who are presented with a "light-off" matrix, are only temporarily disturbed and they rapidly adopt a dominant sequence. In this situation, subjects tend to use mental representations reproducing the "ways" followed by the visual cues when they were available.

These data suggest that, for human subjects as for animals, reinforcement seems to generate stereotyped, functional behavioral units. However, data from other studies show that reinforcement does not inevitably produce stereotypy. For instance, when naive subjects are instructed to discover the rule that determines whether their sequences will be reinforced, they do not develop stereotyped sequences, despite the fact that they are reinforced for each correct sequence (Schwartz, 1982c).

For Wong and Peacock (1986), the development of stereotypy can be attributed to the differential reinforcement of efficiency. Their experiments with human adults support this hypothesis. They have shown that the response sequences become more stereotyped when

subjects have to produce a high physical effort (for one group, the response-buttons are located close together; in the other group, they are more spaced - high effort condition -); when they are rewarded with money for each correct sequence; when a sequence must be completed within a short time-limit to be reinforced (high temporal constraint); or when they are required to perform a concurrent mental task. To use a video display instead of a light bulbs matrix, increases the subjects' motivation, arouses exploratory behaviors and reduces stereotypy.

Contrary to Schwartz, Wong and Peacock have observed that the stereotypy does not interfere with abstracting the rule : their subjects are able to verbalize the necessary condition for reinforcement regardless of their level of stereotypy during training. When stereotyped subjects are asked why they did not use several sequences, they often declare that they did not want to risk losing a reinforcement (point or money). The authors have concluded that, for human subjects, stereotypy is not the inevitable result of reinforcement and that differential reinforcement of efficiency seems to play an important role in the functional development of stereotypy (subjects adopt behavior that enable them to obtain a maximum of reinforcement with a minimum of risks and efforts).

2.2.2.1.2. Operant variability

Studies reviewed in the preceding section show that response variability changes as a function of various factors characterizing the task performed. It can then be asked, and this is an important step further, whether behavioral variability itself is amenable to control by its consequences, as any other dimensions of behavior - such as the force, the duration, the location, etc of a response - , or, in other words, whether selection by reinforcement can operate on variability itself.

2.2.2.1.2.1. Simple operant responses

The few studies in which conditioning the variability of simple responses has been attempted have been carried out on animal subjects.

Schoenfeld, Harris and Farmer (1966) were the firsts to have explicitly conditioned behavioral variations. They reinforced the lever pressing- responses of rats only if the inter-responses intervals belonged to a class which differed from that of the immediately preceding inter-responses interval. For instance, if a lever press concluded one inter-response interval of 5 sec, it was reinforced if the preceding inter-response interval had been longer or shorter by at least 1 sec - if 1 sec was the class resolution in recording inter-responses intervals. Blough (1966) also succeeded in increasing the variability of the inter-responses intervals in pigeons.

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Bryant and Church (1974) have conditioned rats to randomly press on two levers, and Pryor, Haag and O'Reilly (1969) have, in an already mentioned study, succeeded in training sea purpoises to produce motor behaviors that were novel for the species (variability of the response topography).

Though there are only very few of them, these studies show that behavioral variability can indeed be controlled by its consequences.

2.2.2.1.2.2. Complex responses

- Animal studies :

Schwartz (1980, 1982a) - with the Visual Matrix task (5 x 5 matrix) - has submitted pigeons to a peculiar experimental condition, in which reward was obtained for a correct sequence of responses if it differed from the just previous one. The pigeons - naive or pre-trained - developped a sequence which became dominant, in spite of this variability contingency and in spite of the very small number of reinforcements that they obtained (about 40 % of the available reinforcements).

Page and Neuringer (1985), in a critical analysis of Schwartz's results, made the hypothesis that the constraints upon the response, as defined by Schwartz (4 pecks on each key), could account for his failure to condition variability. These authors have removed both this constraint and the matrix of light cues, and they have trained pigeons to emit sequences of 8 responses on the 2 keys. In this situation, the pigeons obtained more that 70 % of the available reinforcements, even if they were to produce sequences different from the 50 previous ones.

By controlling for the intermittence of reinforcement effect, using a Yoked Control Design (reinforcements are delivered according to the same temporal pattern as in the previous session, but they are no more contingent upon the sequences variability), Page and Neuringer have shown that the observed variability is not a spontaneous variability modulated by the intermittence of the reinforcement, but that it is really a function fo the peculiar contingencies that made reinforcement contingent upon response variability.

While sequences of responses emitted by Schwartz's pigeons appeared to be, functionally, integrated and indivisible units, Page and Neuringer's pigeons distributed their responses almost randomly. The differences observed, in this respect, between the two experiments, could be accounted for almost completely by analysing the behavior during the training-sessions preceding exposure to the variability contingencies. During these sessions, the pigeons in Schwartz's experiment had to produce 4 pecks on each key, but with no requirement for variability. On the contrary, the

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pigeons of Page and Neuringer were directly placed in a situation where any sequence of responses was reinforced if it differed from the previous ones.

With an adequate pretraining, Boulanger (1986) has succeeded in conditioning pigeons to vary their sequences of responses, in a situation similar to the one used by Schwartz (4 x 4 matrix). During the pretraining, he had established a responses repertoire characterized by different "minimal" units that could then be combined to solve the task in various ways.

- Human studies :

Replicating on humans his pigeon experiments, Schwartz (1982c) has attempted to condition the variability of sequences of responses (5 x 5 matrix), by reinforcing the sequences that differ from the 2 previous ones. Unlike pigeons, human adults can master this reinforcement contingency, but they develop higher-order behavioral units that contain just enough variability, from trial-to-trial, to guarantee reinforcement : they use a set of stereotyped sequences, which appear in a regular order.

When these pretrained subjects were placed in a situation requiring greater variability (all sequences must be different from each other in a session of 50 trials), the higher-order units broke down and subjects adopted a more variable behavior, though not enough to produce an optimal performance. On the contrary, when naive subjects were placed in the latter situation (maximal variability), they had no difficulty in developing strategies leading to a nearly perfect performance.

These results have led Schwartz to conlude that : "... although contingent reinforcement may not inevitably produce stereotypy, a history of reinforcement seems to interfere with the development of a general strategy necessary for success with a complex task". (Schwartz, 1982c, p.41). The "pretrained or preexposed" subjects would differ from naive ones in their approaching the task less actively (the higher-order units previously created were sufficiently simple to be accurately produced without monitoring) and it could be that this "passivity" interfered with their performance.

However, other data obtained in similar experiments do not support these conclusions. Wong and Peacock (1986) have submitted pretrained subjects to the condition of maximal variability (all the sequences must be different in a session of 50 trials). Their subjects were able to abandon their dominant sequence and to successfully perform the task as fast as naive subjects did. By controlling the level of stereotypy reached by the subjects during the pretraining sessions (for one group, they have increased the level of stereotypy, by introducing task characteristics that demand efficiency), Wong and Peacock have shown that the subjects'

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adaptation to the variability contingency is independent of their initial level of stereotypy.

These results have led the authors to modify - at least for human adults - the conclusion of Schwartz concerning the negative effect of the history of reinforcement : "These findings suggest that behavioral units may not be rigid structures that are emitted in an automatic and invariant manner regardless of changes in reinforcement contingency. In other words, stereotypy does not become counterproductive when the contingency is changed" (Wong and Peacock, 1986, p.157).

2.2.2.2. Selecting the main experimental procedure : the "MATRIX" or Visual Maze.

The essential aims of the experiments was to explore how individuals solve problems in situations in which several solutions are possible, how they modify their solution when the situation is changing and whether they can be trained to produce various solutions. The procedure selected was to provide a measure of behavioral variability. A modified version of the Visual Matrix task was used. It has been borrowed from the procedure originally designed by Vogel and Annau (1973) in their study on animal subjects. In order to motivate the subjects and to maintain their attention long enough, the initial material has been changed to an animated cartoon style presentation on video screen to present the task like a play. This modification was necessary in order to obtain satisfactory data both qualitatively and quantitatively. This procedure could legitimately be called a Visual Maze as well. It presented the desirable properties just mentioned.

In addition, it had the following advantages :

- It can be used with subjects of different ages without modification. Therefore, all the subjects were faced with a strictly identical problem. Differences eventually observed between subjects could not be due to the presentation or to the content of the task.

- It is a non-verbal task : biases tied to the subjects' verbal capacities can be avoided as well as biases involved in the analysis of verbal data. It can be used with animal, allowing for cross-species comparisons, and inquiry into the specificities of human behavior in such situations.

- It allowed analysis of the evolution of subjects' behaviors when they adapted to modifications of situations, providing a dynamical approach (as opposed to traditional tasks used in problem-solving test).

- Finally, all the steps of the experimental procedure and data recording can be implemented on microcomputer, providing on-line

control of the experiment and refined statistical treatment of data.

In brief, the selected task seemed an appropriate one to analyse the evolution of problem-solving behaviors as a function of modifications of the situation with the garantee of a high methodological rigour and of efficient data colllecting and treatment.

2.3. THE DEVELOPMENTAL APPROACH

2.3.1. THEORETICAL BACKGROUND

Examining all the studies on behavioral variability using operant behavior procedures, one is struck by the lack of works adopting developmental perspective. There are none among animal studies. With human subjects, there are only two unpublished studies by Boulanger (1983) and by El Ahmadi (1982). They have shown that behavioral variability increases as a function of age (however, only 2 age groups were taken into account and these studies cannot really be considered as truly developmental).

We contend that the developmental analysis is not only of interest for those who study growing organisms for themselves, but that it is a means to understand adults' behavior. The developmental approach is assumed to be helpful in identifying more accurately crucial variables at work in behavioral variability and in accounting for the strategies that are used by adults when confronted with multiple-solutions problems. It should provide us with informations about the relations between behavioral variability, performance in problem-solving and the possibility to increase behavioral variability on one hand, and about the characteristics of the environment which are taken into account by subjects when solving problems on the other.

The developmental approach is also important in clarifying an issue that is still a matter of debate : are children born with natural flexibility and creativity? Is their potential of creativity exposed to counter-influences from education, that will inevitably restrict it, or is behavioral variability a consequence of environmental influences, and can it be taught ?

It is relevant, at this point, to briefly present Piaget's cognitive developmental theory, not only to show the usefulness of developmental analysis in understanding adults' intellectual functionning, but also because this theory has been at the basis of the choice of age-groups considered in the first experiment. Moreover, some of the tasks selected for comparison with performances and behavioral variability in problem-solving are borrowed or derived from Piaget's experimental procedures.

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In Piaget's conception of intelligence, human cognitive functions are viewed as an active ontogenetic construction by the child interacting with his environment. Basic to such a constructivist conception is the notion that intellectual development necessarily pass through an ordered sequence of stages, up to the mastering of adult logical thinking : the most abstract forms of logical thinking derive from overt action observed in its simplest form in infancy at the sensory motor stage, through the interiorisation and coordination af action at the concrete operation stage.
Two fundamental mechanisms are implied in cognitive development : <u>Assimilation</u> and <u>Accommodation</u>.

- <u>Assimilation</u> is the integration of external element into evolving or completed so-called <u>schemes</u> of action (a <u>scheme</u>, broadly defined, corresponds to a class of behaviors). No behavior constitutes an absolute beginning. It is always grafted on previous schemes and therefore amounts to assimilating new elements to already constructed structures, innate or previously acquired (for example, the sucking reflex is applied to a large number of objects, obviously as a means for collecting information). However, if assimilation alone were involved in development, there would be no variations in a child's psychological structures. He would not acquire any new content and would not develop further. Assimilation is therefore never present without its counterpart : accommodation

- <u>Accommodation</u> is the process by which assimilatory schemes are in turn modified by the elements they assimilate (using again the simple example of sucking behavior, the child adjusts his sucking behavior to adapt to the characteristics of new objects). Hence, cognitive adaptation and development result from an equilibrium between assimilation and accommodation.

Three main periods of development can be distinguished. They appear in a fixed sequence because each of them is a necessary condition for the next one to proceed.

- The sensorimotor period lasts until approximately 1 1/2 or 2 years of age. During this period, the child elaborates schemes of actions, that is to say, organizations of actions which can be generalized from one situation to another.

- The period of representative intelligence leads to concrete operations. Before about 7 or 8 years, children grasp various characteristics of a situation (or of a material) but they cannot integrate them into a system. They cannot anticipate the results of their actions, they base their judgements or behaviors on the immediately perceived characteristics of the situation, and they fail to take into account the relations existing between all the elements of a situation. As an example, if instructed to put some order in a set of objects differing in various dimensions, such as size, color, shape,

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type of material, etc (classification task), subjects at that stage will use partial criteria or use only the most salient properties, such as size and color, and will reveal unable to switch to other criteria. Or, in the well-known "conservation task", pouring a liquid from one container to another - say, narrower and higher than the first one - the child will conclude that the quantity has changed because the level is higher, being unable to coordinate the two dimensions and see that they compensate for one another.

At about 7 or 8 years, (operative stage), the reactions are very different. At this stage, children take into account one aspect after another, manipulate, transform and coordonate the relations into a system. The child's thought becomes reversible, that is to say that he can conceive of undoing what he is doing and vice versa. He is able to anticipate the results of his actions and behave according to pre-established plans. In classifications, for example, he/she is able to keep in mind the initial arrangement and the successive transformations carried out on the material; all actions can be logically cancelled. "Mobility of thought" is one main characteristic of accessing to the operative stage. This "mobility" or "intellectual flexibility" is at work in all classical tasks explored by Piaget, i.e. in conservation, seriation and classification. Classification is undoubtedly where it appears most clearly in observable behaviors. As already mentioned, in a classification task, the subject is asked to organize a set of elements (objects displayed before him/her) in any way he/she wishes to do. After his/her first arrangment, he/she is asked to carry out another classification and so on. Inhelder and Piaget (1967) have named the process at work in this type of behavior : retroactive mobility.

This period extends, crudely defined, to the age of 11. It can be summarized by saying that the child masters all main logical operations but that his reasoning still needs the support of concrete situations.

- After this period, logic is applied not only to relations in concrete situations but also to relations between propositions at a purely symbolic level. It is the formal operative stage that will be typical of adult intelligence.

According to Piaget, four factors explain cognitive development :

1. Maturation : the effect of which consist essentially in opening new possibilities for development. For example, the progressive coordination between vision and prehension is possible only when the neural substrate has adequately developed.

2. The experience acquired through active contact with the environment : By interacting with their environment, children acquire knowledges relative to particularities and properties of the physical and social environment, and knowledges relative to consequences of their own activities on the environment.

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3. The influence of the social environment (language, educational background given by family or school).

While these factors can accelerate or delay cognitive development, they are not sufficient to explain the sequential order of development. Both social influences and physical experience can have effect on subject's development only if he/she is capable of assimilating them, which means that cognitive structures and processes have reached an adequate level. What is taught, for example, is effectively assimilated only when it gives rise to an active reconstruction by the child (cf the mechanisms of assimilation -accommodation presented above).

4. The constructive aspect of development is explained, after Piaget, by appealing to a fourth factor : equilibration.

Equilibration can be defined as a self-regulating process involving a set of active reactions of the subject to external disturbances, inducing disequilibration.

Especially relevant to our concern is the view of Piaget as to the role of variations. These are closely related to his notion of equilibration, because subjects modify their behaviors or their cognitive structures as a function of disturbances in environment, in order to reach a new level of equilibrium. However, what has to be explained is why the subject, at a certain level of development, "feels" the contradiction between the structure characterizing his/her behavior and the characteristics of the environment, and why he/she engages in readjustments. What is needed here is some sort of behavioral variability, paving the way for innovations, new strategies, new coordinations.

Taking into account the cognitive development as described by Piaget, subjects of our first experiment were selected into for different age groups. Normally, the subjects belonging to each of these age groups, should be characterized by a certain level of cognitive development. Subjects 5-6 years old are presumably at the pre-operative stage, subjects 9-10 years old at the concrete operative stage, and subjects 14-15 years old and adults at the formal operative stage.

2.3.2. SELECTING TASKS ON "MOBILITY OF THOUGHT"

In research concerning the evolution of problem-solving behaviors as a function of age, useful guidelines are offered by the cognitive developmental levels as defined in Piaget's theory. In previous research carried out in our laboratory, Piagetian concepts have been used for the analysis of behavioral flexibility (Botson and Deliège, 1976; Deliège, Botson and Vanhulst, 1984). These experiments, which cannot be described in details here because available space does not permit, led to the conclusion that the difficulties encountered by children in the resolution of concrete problems involving creative solution were mainly tied to their

"difficulties to change", i.e. to leave behind an already tried solution and explore another one. For example, children had difficulties to employ usual objects in an unusual way (e.g. to use a box full of spaghetti to represent the main part of a locomotive), or to pull apart and recombine objects or pieces of objects (e.g. to dismantle a toy plastic kettle and use the yellow part of it to complete the heart of a flower). As a step toward systematic training of flexibility, the authors have explored the spontaneous tendency to change - or the aptitude to switch from one behavior to another when confronted to a standard situation - as a function of age. Appropriate training can only be based on knowledge of developmental stages, if there are any.

As already mentioned in section 2.2.1., two types of change were considered. One of them involved a practical manipulation - "handling" change -, the other a "cognitive" change.

In the "handling" change tasks, subjects (from 4 y.o. to 12 y.o.) had to change the orientation of similar blocks in order to embed them in holes of different shapes.

The "cognitive" change tasks (or "intellectual flexibility") were borrowed or derived from Piaget's procedures in his studies on "mobility of thought" (see section 2.3.1.). Directly borrowed were the spontaneous classification test and the successive dichotomies test. An especially designed situation, the "serial classification task", was added, that combines classification and seriation operations. In this situation, the subject is presented with an array of objects, varying along several dimensions, but ordered in space in such a way that at any point, the series can be dichotomically cut, with the objects on one side sharing a common property, but lacking an additional property shared by the objects on the other side. The subject's task is to complete several series by inserting at a given point an appropriate object, selected out of a multiple choice display. Two situations are possible : one where the perceptual impression fits to the logic of the system (perceptual serial classifications) and one where the perceptual impression does not fit or even conflicts with the reasoning (non-perceptual serial classifications).

One advantage of this procedure is that there is only one solution to each series.

While Inhelder and Piaget considered that the 9 y.o. children are able to anticipate all the possible criteria of classification and to behave in a systematic and exhaustive way as a function of a pre-established plan, Botson and Deliège's observations showed that this age was not a turning point between the stage of "trials and errors" processes and the stage of complete mobility. Older subjects, adolescents and even adults failed when they were confronted with a material including more than 3 or 4 criteria of classification, or with a material in which the logical organization conflicted with the perceptual characteristics (non-perceptual serial classifications). The

mobility seemed to be hindered by perceptual fixations, at all stages of intellectual development.

Comparing the evolution of the "handling flexibility" with that of "cognitive flexibility", the authors concluded that the two types of flexibility evolve in parallel. In both cases, it was the most perceptually salient characteristics that misled the subjects, preventing them to take the useful characteristics into account. Thus, difficulties in "decentration", i.e. in switching to another look at this problem, seemed to be the source of errors in both types of tasks.

A qualitative analysis of the results of previous researches on behavioral variability carried out in our laboratory (El Ahmadi, 1982; Boulanger, 1983) also suggested that performance and variability in the Visual Matrix task were a function of the subjects' cognitive developmental level and of the degree of "abstractness" in their approach to the task.

These studies suggested that it could be of interest to assess the subjects' cognitive capacities (particularly, the "mobility of thought") and to relate them with the subjects' performance and variability in the Visual Matrix task.

The choice of specific "cognitive" tasks was determined by the age of subjects, by the possibility to use at least one common task for two successive age groups and to adopt a standardized procedure. Tasks involving concrete manipulation were prefered to tasks involving verbal behavior.

- The seriation, the spontaneous classification and the inclusion quantification tasks permitted to evaluate the cognitive stage (in the Piagetian nomenclature) of the 5-6 y.o. and of the 9-10 y.o. The successive modifications of classifications and of dichotomies allowed to assess their mobility of thought. The difficulty of the tasks was adapted to subjects' age (simple or multiplicative seriation; level I or level II classification).

- The serial classification task in the simple version (involving only perceptually consistent items) was used with the 5-6 y.o. and with 9-10 y.o. The version with perceptually non consistent items was used for the 14-15 y.o. and the adults. The serial classifications allowed to complete the informations obtained with the Piagetian classification tasks (for Nursery, Elementary and Secondary School Students) and to assess the "mobility of thought" of adults.

- The permutation task (Piagetian task of the formal logic stage) was proposed to adolescents and adults. It aimed at assessing the capacities for abstracting and generalizing rules and to resort to a systematic procedure in the search of all possible permutations.

2.4. SOCIO-CULTURAL FACTORS

Educational, professional and socio-cultural factors are of such a general and persistent presence in people life that they can be expected to produce deeply rooted attitudes in individuals.

There are, to our knowledge, no studies bearing directly on the relations between the subjects' socio-economical origin, their level or their type of educational background, their professional activity, on one hand, and some measure of their behavioral variability, on the other hand. However, these variables have been shown to be relevant in some studies of cognitive functioning.

So, Lautrey (1976, 1980) has shown that life conditions linked to the parents' socio-economic level, determine in part their educational practices, which in turn influence their children' intellectual development. He has observed functional aspects of the subjects' cognitive activity, namely the way they switch from a "schema" to another one when confronted to the constraints of reality, or, put in other words, how a child reacts to a disturbing fact, and eventually reorganizes his/her behavior in order to adjust to it and integrate it. Lautrey has defined 3 types of family educational practices, which are characterized by their degrees of stability and of disturbance. A child may live in any one of these environments :

- random : characterized by the absence of rules
- rigid : rules are applied whatever the circumstances
- flexible : the application of rules is modulated by the circumstances

The author has noticed that children coming from a flexible type environment show higher readiness to reorganize their behavior in order to integrate disturbing fact. This can be explained by the fact that these children are faced with disturbing events more frequently that children coming from a rigid environment, and that .hey have more occasions to improve their anticipations by taking these disturbing events into account, than children coming from a random environment.

This attitude towards events hindering assimilation seems to be a rather general characteristic of personality.

The author has also observed that the flexible environment is more often adopted by parents of the highest socio-cultural level, while the rigid educational environment is more frequently linked with lowest socio-cultural level. A previous research by Busse (1969) had already shown that the flexibility of thought is linked to the family educational practices and that a middle level of parental control seems to be the most favourable to the development of flexibility.

Other works suggest that some aspects at least of the cognitive functioning could be influenced by specific training but are linked to the level and to the type of educational background.

Bodson and Deliège (1976) have shown that the successive steps leading to the highest levels of mobility of thought (in the piagetian terminology) correlate, after elementary school, with the superior level of the secondary studies and with the specialized university studies (especially, mathematical studies). Moreover, subjects who have followed a training for manual workers, have a mobility of thought lower than subjects who have followed secondary studies of general type, and University students who are in a literary section have an intellectual mobility, at least as assessed by this type of test, lower than University students in mathematics.

Even if it can be assumed that the choice of a given school curriculum is partly determined by an individual's aptitudes and tastes, it seems that, in turn, this sort of training to which he is or has been exposed during school education is an important factor in shaping further these aptitudes, as exhibited in problem-solving, especially those requiring flexible approaches.

The studies mentioned above have incited us to include these factors in the study of variability. One could indeed suspect that the educational background is important in favouring or restricting variability. This is a very practical issue since there is now a widespread concern for more "flexibility", "creativity" and the like in all aspects of social and professional life. Therefore, in the second part of our study, variability and performances observed in problem-solving have been analysed as a function of the level and type of educational background of subjects. Adolescents and mainly adults of 18-27 years old (militiamen) were taken into account.

2.5. COGNITIVE STYLES AND VARIABILITY

The concept of "cognitive style" relates to the typical way that an individual interprets reality and derives meaning from his/her experience. This definition is in terms of processes rather than structure or traits and it concerns perceptual, intellectual and social activities. It allows to characterize the mode of approach that a subject uses in a variety of situations.

2.5.1. THE "FIELD DEPENDENCE / INDEPENDENCE" COGNITIVE STYLE

Many cognitive style models have been developped. One of the best known is the field dependence / independence elaborated by Witkin (1977). It refers to the two extreme poles of a continuum, rather than to a typology.

Field - independent people" ... can apprehend items as discrete from their backgrounds when the field is organized and can impose structure on a field when the field has little inherent structure ..."

Field - dependent people have greater difficulties to solve problems which require "... taking an element critical for solution out of the context in which it is presented and restructuring the problem material so that the element is now used in a different context." (Witkin and Goodenough, 1981).

Several authors have studied the relations between the subjects' cognitive style (field-dependence / field-independence) and their developmental level, as assessed in Piagetian situations. Positive relations have been found between the field-independence and the performances in conservation tasks (Fleck, 1972; Dolecki, 1967; Finley, Sola and Cowan, 1977; Pascual-Leone, 1966, 1969; Nodelman, 1965; Huteau and Rajchenbach, 1978; cited by Huteau, 1980) and in tasks relative to the space representation (La Crosse, 1966; Pascual-Leone, 1969; Satterly, 1976; cited by Huteau, 1980). However, no significant relation has been found between the subjects' cognitive style and the performances in multiplicative classification tasks and in class inclusion tasks (Pascual-Leone, 1969; Grippin, Ohnmacht and Clarck, 1973; Finley et al., 1977; cited by Huteau, 1980) on one hand, and the performances in seriation tasks (Huteau and Rajchenbach, 1978; Grippin et al., 1973; cited by Huteau, 1980) on the other hand. The mobility in successive dichotomies tasks proves to be moderately related with field-independence *in children only* (Pascual-Leone, 1969; O'Bryan and Mac Arthur, 1969; cited by Huteau, 1980). The analysis of the relations between the cognitive style and the capacity to use combinatory operations, gives contradictory results, depending on the material used (Baber, 1976; Huteau and Rajchenbach, 1978; Longeot, 1974; Neimark, 1975; Pascual-Leone, 1969; Saarni, 1973; cited by Huteau, 1980). On the contrary, positive relations have been found between the field-independence and the mastery of the notion of probability (Pascual-Leone, 1969; Huteau and Rajchenbach, 1978; Niemark, 1975), volume conservation (Ghuman, 1977; Huteau and Rajchenbach, 1978; Pascual-Leone, 1969) and experimental reasoning (Saarni, 1973; Lawson, 1976; Lawson and Wollman, 1977; Pulos and Adi, 1978).

Thus, as noted by Huteau : "The review of the literature about this topic shows an interaction between cognitive style and characteristics of the situations chosen to assess the developmental level..." and it supports the hypothesis according to which ... "the strength of the relationship between field-independence and efficiency in Piagetian tasks is linked to the pregnancy of figurative components when these make the problem more difficult ..." (as it is the case for the space representation for the conservation tasks) (Huteau, 1980, p. 35). As a rule, field-independent subjects reveal themselves more efficient when destructuration-restructuration capacities are needed (as in tasks where several factors have to be dissociated).

In the sphere of concept learning, researchers have shown that the effects of the salient cues are more accentuated for field-dependent subjects. They experience difficulties of learning when the cues that were useful in solving a given problem are no longer relevant in a new problem. (Ohnmacht, 1966; Zawel, 1970; cited in Witkin et al., 1978, p. 322).

Field-dependent subjects tend to adopt a passive approach to problems, rather than use a strategy of verification of hypothesis (Nebelkopf and Dreyer, 1973; cited by Witkin et al., 1978, p. 320). They are less efficient than field-independent subjects in learning without reinforcement (Fitz, 1971; Paclisanu, 1970; Steinfeld, 1973; cited by Witkin et al., 1978, p. 316).

In view of all these results, it seemed appropriate to look for relations between the performance observed in the Visual Matrix Task, which includes visual cues, and the degree of field-dependence / independence of the subjects.

The French version of the Group Embedded Figures Test was chosen to differenciate the subjects according to their field-dependence or independence. This test was proposed only to adolescents and to adults because there was no French version of it adapted for children.

2.5.2. THE "ASSIMILATOR / EXPLORER" COGNITIVE STYLE

Another model of cognitive style has been proposed by Kaufmann, 1979 under the label "Assimilator - Explorer". This author has shown with a modified version of the Luchins' jar-problems, that some subjects spontaneously change their method of solution. On the contrary, other subjects always use the same method, even if easier methods are possible. Kaufmann considers that these two types of subjects can be characterized by two different cognitive styles : respectively, the "Explorer" and the "Assimilator" styles. "Explorers" can change their method when the situation requires it easier than "Assimilators".

The strategies used by the two types of subjects defined by Kaufmann could be compared with the two different kinds of thinking identified by Guilford (1950; 1967) : divergent thinking and convergent thinking. The most important of these for problem-solving is the divergent thinking which is assumed to be critical in producing novel approaches to problems, involving not logical thinking (contrarily to the convergent thinking) but thinking that is "free" and allowing the problem solver to break away from old habits of thought.

In a certain sense, Kaufmann also approached the subject's spontaneous behavioral variability and, as he noted himself : "... it would be interesting to employ an experimental situation of the kind

developped above (the modified version of Luchins' jar-problems) as a basis of prediction of problem-solving performance in tasks that require variability in perspectives and novel approaches in order to be solved in a satisfactory way." (Kaufmann, 1979, p. 108).

Adults of our third experiment have been submitted to Kaufmann's task. Their performance expressed in terms of cognitive style"Assimilator or Explorer" has been compared with their behavior in the Visual Matrix Task .

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CHAPTER 3

METHODS -
GENERAL DESCRIPTION

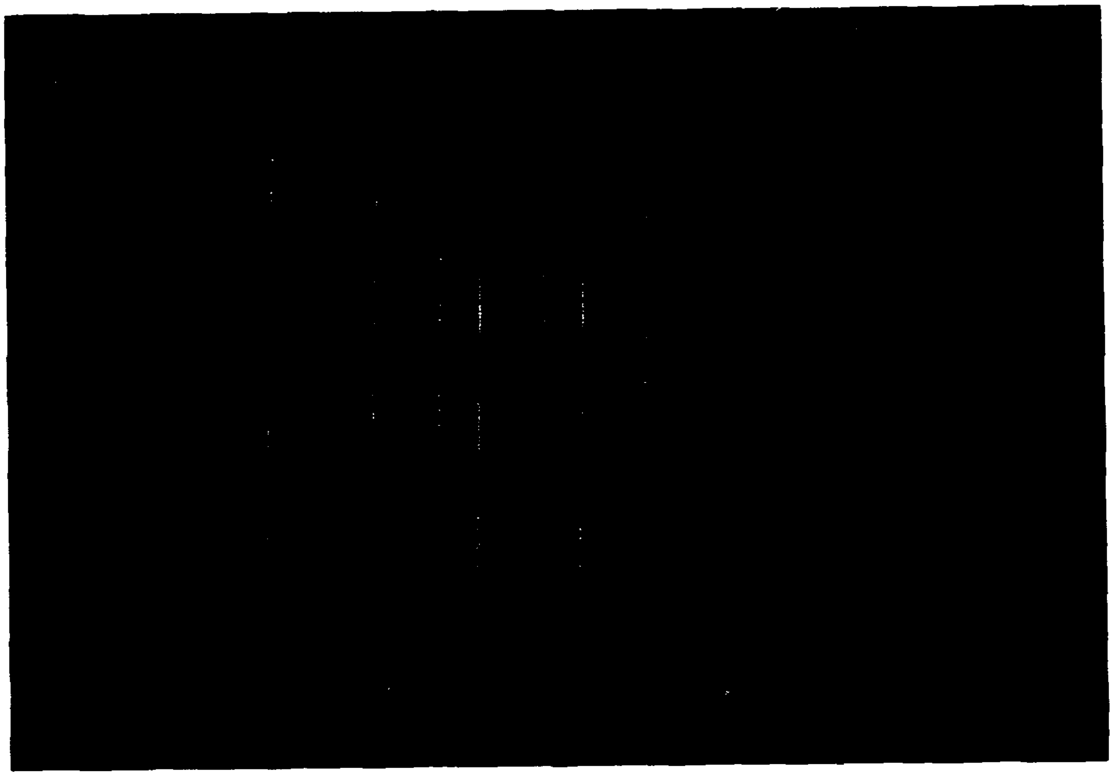
In this chapter, those aspects of methods put to wotk that are common to the whole set of experiments will be presented. A detailled description of each task used will be given, including material, procedure and treatment of data. General procedure common to all experiments will be complemented by methodological aspects specific to each experiment, presented, for the sake of clarity, in table form - details on these specific aspects being presented later in the chapters devoted to experimental report proper.

3.1. VISUAL MATRIX TASK

- Material and procedure

In order to assess behavioral variability, a modified version of the Visual Matrix Task has been used. It is borrowed from a procedure originally designed by Vogel and Annau (1973) in a study on animal subjects. As already pointed out, it could legitimately be called a Visual Maze as well.

The 4 x 4 light bulbs matrix display used in Vogel and Annau (1973) experiment was changed to an animated cartoon style presentation on video screen of 20 x 27 cm (Commodore, model 1701). Two response-buttons were placed in front of the video screen. This equipment was connected to a microcomputer (Commodore 64) for on-line control of the experiment, including video-screen display and recording of responses.



Subjects were sitting at a table in front of the response-buttons and of the video screen and they were presented with a bank building with four floors and four windows at each floor. A moneybag was visible in the upper left window at the begining of each trial.

A response on the left button had the consequence of moving the bag to the next window to the right and a response on the right button similarly resulted in displacing the bag one step downward. The trial was completed and reinforced when the bag reached the bottom right window.

A correct sequence was defined as a sequence in which the "goal" (bottom right window) was reached after six responses -three on each button- in any of the 20 possible com'.nations. No tolerance was made for extra responses (a 4th response on a given button). In such cases, the trial was terminated and another trial was initiated. There were 30 possible incorrect sequences.

Every reinforced sequence was also followed by a new trial. They were separated by intertrials intervals of 6.3 seconds (time between the last push on one button and a new possibility to begin a responses sequence). When a sequence was correct, the bag fell into a wheelbarrow pushed by a securityman, who took it to a safe pictured on the screen close to the bank building. Each bag put into the safe added one point to a counter shown on the screen, and the safe filled up a little (always by the same amount). If the sequence was incorrect, the bag fell into the wheelbarrow, but a thief would arrive and take it away.

- <u>Instructions</u> : "You see, here is a bank building with windows. Behind one of them, there is a moneybag that you can move by pressing the buttons which are in front of you. You must try to put as many moneybags as possible in the safe.

If you succeed, a securityman will help you . But, if you make a mistake, a thief will arrive and he will take the moneybag away. So, you will get no point.

Take care, you can press only one button at a time."

- <u>Different matrix types were used</u> :

The matrices N, R and D were used in the first experiment and the matrices N, D, D10 and C were used in the second and in the third experiments.

1. <u>Normal Matrix (N)</u> :
   The matrix and the reinforcement principles were those described above. Each correct sequence was rewarded.

2. <u>Random Matrix (R)</u> :
   Though the rules remained the same as far as sequences of responses were concerned, the visual display did not give any useful information. After a response, the bag moved randomly to another window and no particular window was a goal or initiated a trial.

3. <u>Normal Matrix with Differential Reinforcement (D)</u> :
   The principles were the same as in N, except for the rule of reinforcement. A correct sequence was reinforced if and only if it was different from the two previous ones (correct or incorrect).

4. <u>A second type of Normal Matrix with Differential Reinforcement (D10)</u> :
   A correct sequence was here reinforced if it was different from the ten previous ones (correct or incorrect).

TABLE 01 : LIST OF MATRIX TYPES

1. **N** : Normal Matrix

   All correct sequences reinforced

2. **R** : Random Matrix

   All correct sequences reinforced but the visual display does not give any useful information

3. **D** : Normal Matrix with Differential Reinforcement

   A correct sequence reinforced if different from the two previous ones

4. **D_{10}** : Second type of Normal Matrix with Differential Reinforcement

   A correct sequence reinforced if different form the ten previous ones

5. **C** : Matrix with prescribed sequences

   Only three specific sequences reinforced

5. Matrix with prescribed sequences (constrained : C) :
Only three particular sequences were reinforced: A'.BABB, BAABAB, ABBAAB (with A = one push on the right button and B = one push on the left button).

Each subject was individually submitted to several sessions of 50 trials each.

Abbreviations and full labeling for all 5 matrix types are given in Table 01, also reproduced on a separate sheet to help the reader in the results section.

- Treatment of data :

Ten indices were selected to provide optimal information about performance and behavioral variability in the Visual Matrix Task. Their values were computed for each subject and for each session of 50 trials.

1. The percentage of correct sequences : **% CS**

2. The percentage of the dominant sequence : **% DS**
It is the percentage of the sequence that was the most often emitted by a subject in a session. It can differ, for the same subject, from one session to another.

3. The uncertainty of sequences : U(S)
This index is derived from Information Theory (Shannon and Weaver, 1948). The mathematical model associated with the theory provides an adequate way to estimate the degree of variability within the system being considered, or conversely, the degree of organization. When one comes to measure it, variability is of course a relative, not an absolute concept. The model permits to estimate the information of a message Xi : ($I(Xi) = -\log_2 pi$) with pi being equal to the probability of occurrence of Xi in a set of messages : $X = \{ X_1, X_2, X_3, \ldots\ldots X_n \}$. The global "information" of the set of messages, called uncertainty U(X), is equal to the weighted sum of the information of the different messages :

$$U(X) = -\sum_{i=1}^{n} pi \log_2 pi$$

The uncertainty of sequences U(S) was computed on the set of sequences produced by one subject during one session of 50 trials :

$$U(S) = -\sum_{i=1}^{50} p_i \log_2 p_i, \quad \text{with } p_i = \frac{\text{sequence i frequency}}{50}$$

This index is expressed in bits - the classical unit in Information Theory - since logarithms are in base 2. U(S) is maximum if all sequences are equiprobable : U(S) = $\log_2 50 = 5.64$... It is 0, if only one sequence is emitted during the session. This index is used to estimate the general degree of variability of the sequences in a session.

4. The number of different correct sequences : NCS. (0 to 20).

5. The uncertainty of correct sequences : U(CS).

$$U(CS) = -\sum_{i=1}^{20} p_i \log_2 p_i, \quad \text{with } p_i = \frac{\text{correct sequence i frequency}}{\text{total number of correct sequences produced by the subject}}$$

This index is computed as U(S) (see 3 above). It can vary from 0 to 4.32

6. The number of different incorrect sequences : NIS. (0 to 30).

7. The uncertainty of incorrect sequences : U(IS).

$$U(IS) = -\sum_{i=1}^{30} p_i \log_2 p_i, \quad \text{with } p_i = \frac{\text{incorrect sequence i frequency}}{\text{total number of incorrect sequences produced by the subject}}$$

The index is computed as U(S) (see 3 above). It can vary from 0 to 4.90.

8. The number of correct sequences differing from the 2 previous ones (correct or incorrect) : NSD_2.
It corresponds to the number of reinforcements in the matrix D.

9. The number of correct sequences differing from the 10 previous ones (correct or incorrect) : NSD_{10}.
It corresponds to the number of reinforcements in the matrix D10.

10. The number of sequences which are part of the 3 reinforced sequences in the matrix C : NSC
It corresponds to the number of reinforcements in the matrix C.

Abbreviations and full labelling for all ten indices are given in Table 02., that is reproduced on a separate sheet to help reading.

The last two indices (9 and 10) were only used in the experiments 2 and 3.

A supplementary index was selected that was thought to possibly bring more qualitative informations about the organization of subjects' behaviors: the dominant sequence type (DS). All the dominant sequences were distributed into four groups, according -to the most frequent DS types.

With A = one push on the right response-button and B = one push on the left response-button , we have :

1. Corner sequences (AAABBB or BBBAAA),
2. Diagonal sequences (ABABAB or BABABA),
3. Other correct sequences (AABBBA, BABBAA, ..., for example),
4. Erroneous sequences (AAAA, BBAABB, ..., for example),
5. Constraint sequences : this category includes the 3 sequences reinforced in the matrix C (AABABB, BAABAB, ABBAAB).

In the results section of chapters 4 and 5, results in the matrix will be presented under two headings, performance and variability.

Performance refers here to those aspects of the subject's behavior which contribute to efficiency, i.e. to reinforcements.

The performance of subjects is assessed by the following indices :

- % CS in all matrixes (it corresponds to the number of reinforcements in the matrices N and R).
- NSD_2, NSD_{10} and NCS in the matrixes D, D_{10} and C, respectively (these indices correspond to the number of reinforcements in these matrixes).

Variability refers specifically to the changes exhibited by the subject in sequences he used.

The global variability of subjects is assessed by % DS and U(S) in all matrixes.

In addition, variability of correct sequences and variability of incorrect sequences have often be considered separately. They have be assessed by NCS and U(CS) and by NIS and U(IS), respectively.

Table 02 : **LIST OF INDICES**

1. **% CS**

   Percentage of Correct Sequences.

2. **% DS**

   Percentage of the Dominant Sequence.

3. **U (S)**

   Uncertainty of Sequences.

4. **NCS**

   Number of different Correct Sequences.

5. **U (CS)**

   Uncertainty of Correct Sequences.

6. **NIS**

   Number of different Incorrect Sequences.

7. **U (IS)**

   Uncertainty of Incorrect Sequences.

8. **NSD_2**

   Number of correct Sequences Differing from the **two** previous ones (correct or incorrect).

9. **NSD_{10}**

   Number of correct Sequences Differing from the **ten** previous ones (correct or incorrect).

10. **NSC**

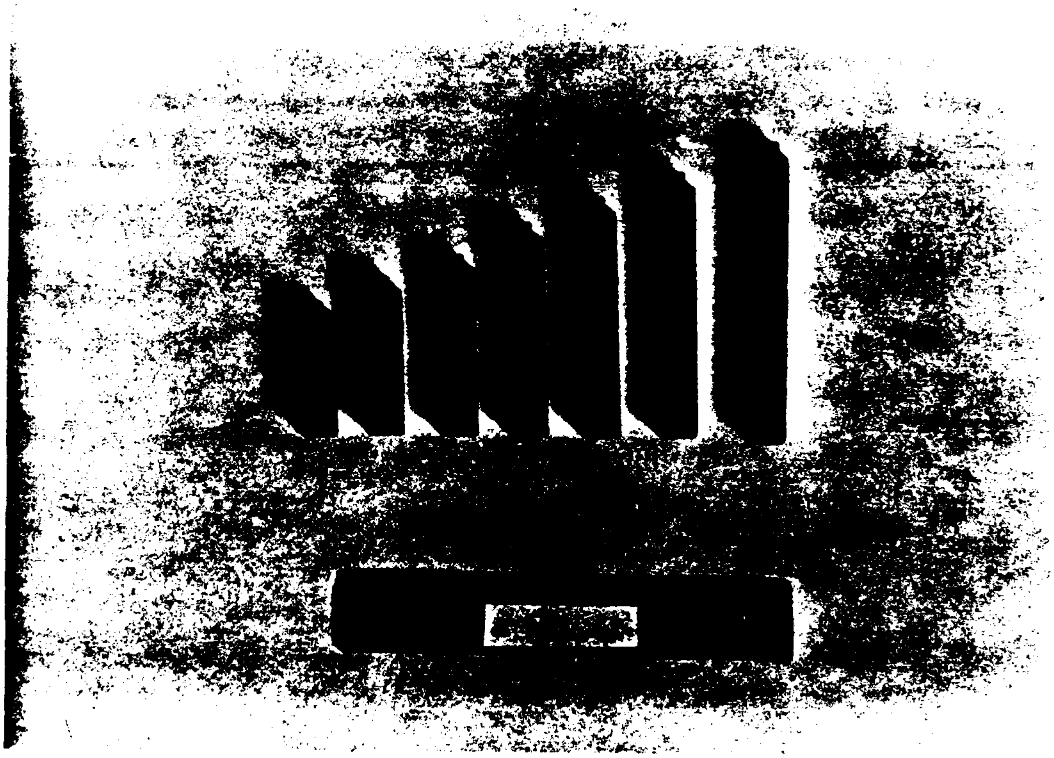
    Number of Sequences which are part of the three reinforced sequences in the matrix C.

3.2. OTHER COGNITIVE TASKS

In this section, tasks that were used for comparison with the performance in the MATRIX are described. The source in the literature where more details can be found, is mentioned immediately after the label. The experiment (1, 2 or 3) and age group(s) in which the task has been used are also mentioned.

3.2.1. SIMPLE SERIATION AND INTERCALATION (Piaget and Inhelder, 1967) (Experiment 1 : 5-6 y.o.)

Material :
6 wooden sticks of different lengths (5, 6, 7, 8, 9 and10 cm).



Procedure :

a) The 9 cm stick was taken away. The task was to seriate the other five according to length.
b) If seriation was correct, the subject was asked to insert the missing stick in the correct position.

Performance on the task (and the procedures employed by the subject) were observed and directly transcribed on paper by the experimenter.

Treatment of data :

Subjects were put into two categories, the performance criteria for being put in cat. 2 presumably showing higher cognitive level than those for cat. 1.

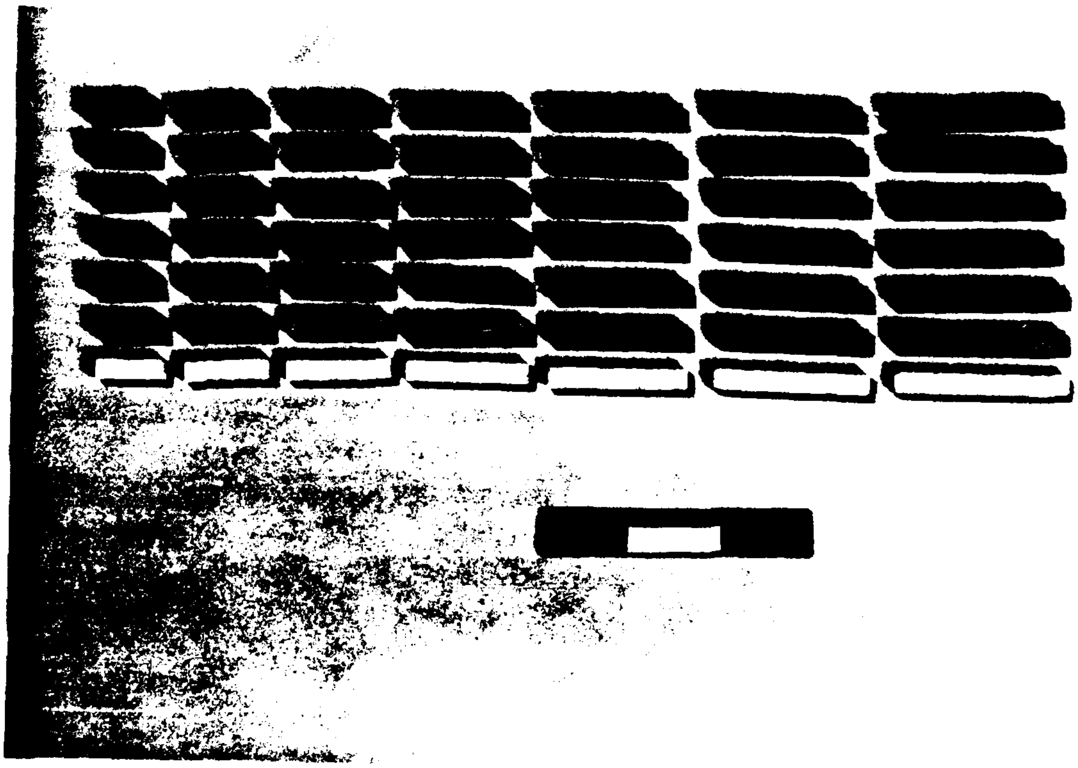
Cat. 1 : subjects did not correctly arrange the elements (examples: they "drew" a house; they assembled the elements by two or by three: they formed the top of stairs, but without taking into account the stairs basis.)

Cat. 2 : subjects made a correct seriation (with or without the direct insertion of the remaining element).

3.2.2. MULTIPLICATIVE SERIATION (Piaget and Inhelder, 1967)
(Experiment 1 : 9-10 y.o.)

Material :

7 x 7 sticks that could be seriated on the basis of size (7 different sizes : 4,5,6,7,8, 9 and 10 cm) and color saturation (7 different color saturations for 7 sticks of a determined length).



Procedure :

The subject was to order all the 49 sticks according both to size and color saturation.

Instructions :

"You see these sticks, they are of different sizes and color intensities. Could you set them in order ? Do as you like".

- If the subject did not understand the instructions, he/she was further instructed to set all the wooden sticks in order both from the smallest to the longest, and from the lightest to the darkest.
- If the subject could not carry out his/her seriation, the experimenter began the seriation and the subject was asked to complete it.

Performances on the task, and the procedures employed by the subjects were observed and recorded.

Treatment of data.

Subjects were put into three categories, the performance criteria for being put in cat. 3, presumably showing higher cognitive level than those for cat. 2 and the performance criteria for being put in cat. 1, presumably showing lower cognitive level that those for cat. 2.

Cat. 1 : subjects arranged the elements according to only one dimension (length or color saturation) or correctly completed the example given by the experimenter.

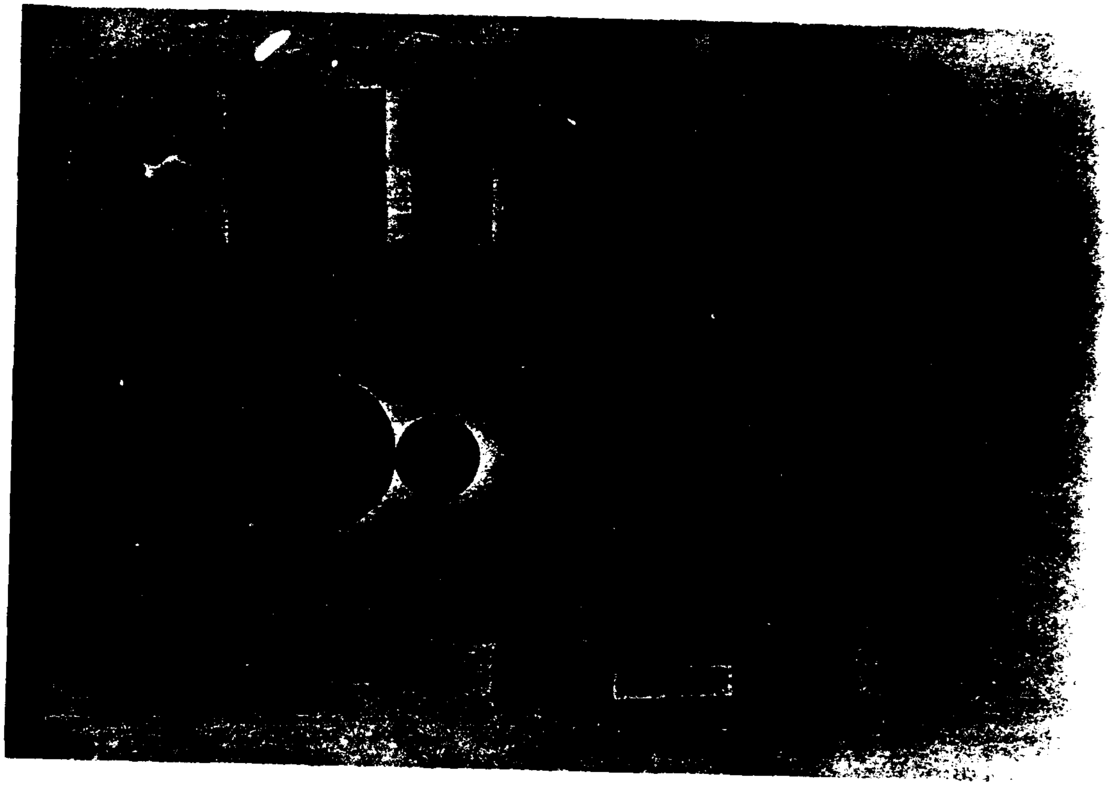
Cat. 2 : subjects arranged the elements, according to one dimension and rearranged this first seriation, according to the second dimension.

Cat. 3 : subjects arranged the elements, according to the two dimensions, simultaneously.

3.2.3. FREE, DICHOTOMIC AND MULTIPLICATIVE CLASSIFICATIONS. LEVEL 1 : 3 CRITERIA OF DICHOTOMY (Piaget and Inhelder, 1967) (Experiment 1 : 5-6 y.o; 9-10 y.o.)

Material :

- 8 elements that could be sorted on the basis of size (7 x 7 cm and 7 cm Ø; 3,5 x 3,5 cm and 3,5 cm Ø), color (blue; yellow), or shape (disk; square).
- A sheet of paper that could be divided in 2 or 4 parts by two removable partitions.



Procedure :

a) Free classifications :

- All the elements were displayed in disorderly manner on the table in front of the subject.
- The subject was asked to group the elements in any way he/she wished to.

Instructions :

"You see, these pieces are all mixed up, could you set them in order putting together those that are alike ?"

- After his/her first arrangement, the subject was asked to carry out another classification.

Instructions :

"Could you set in order the pieces again, but in another way, always putting together those that are alike ?"

b) Dichotomies :

- The elements were mixed up and the sheet of paper (divided in 2 parts) was placed right in front of the subject.
- The subject was asked to distribute the elements in two sets.

Instruction

"Could you arrange the pieces by making only two sets ?"

- Finally, he/she was asked to make yet 2 different dichotomies.

c) Multiplicative classifications :
- The elements were mixed together and the sheet of paper was divided in 4 parts by two removable partitions.
- The subject was asked to distribute the elements in 4 sets.

Instructions :

"Would you arrange these pieces in 4 sets; if one takes this separation (vertical) off, these sets (experimenter designates sets) must fit together, and if one takes this other separation (horizontal) off, these other 2 sets must fit too (designates).

- As for the dichotomies, the subject was asked to make two additional multiplicative classifications.
- The subject was asked to justify each of his/her performances.
- Performances on the task, the procedures employed by the subject and his/her justifications were observed and recorded by the experimenter.

Treatment of data :

For the free classifications test, subjects of 5-6 y.o. were put into two categories. The performance criteria for being put in cat. 2, presumably showing higher cognitive level than those for cat. 1.

Cat. 1 : subjects did not spontaneously make any classification (for example, they put the totality or a part of elements into a line; they assembled some elements to make a picture).

Cat. 2 : subjects spontaneously made several under -collections, one dichotomy or one multiplicative classification (for example, the objects distribution could be represented as follows :

yellow circles	yellow squares
blue circles	blue squares

For the subjects of 9-10 y.o., these 2 categories were modified as follow :

Cat. 1 : subjects spontaneously classified the objects into 2 collections (one dichotomy) or divided the objects into 2 collections which were itselves divided into 2 under-collections.

Cat. 2 : subjects put spontaneously together, by trials and errors, the different under-collections, according to their common characteristics (one multiplicative classification) or executed, directly, a correct multiplicative classification.

The numbers of correctly justified dichotomies (from 0 to 3) and the number of correctly justified multiplicative classifications (from 0

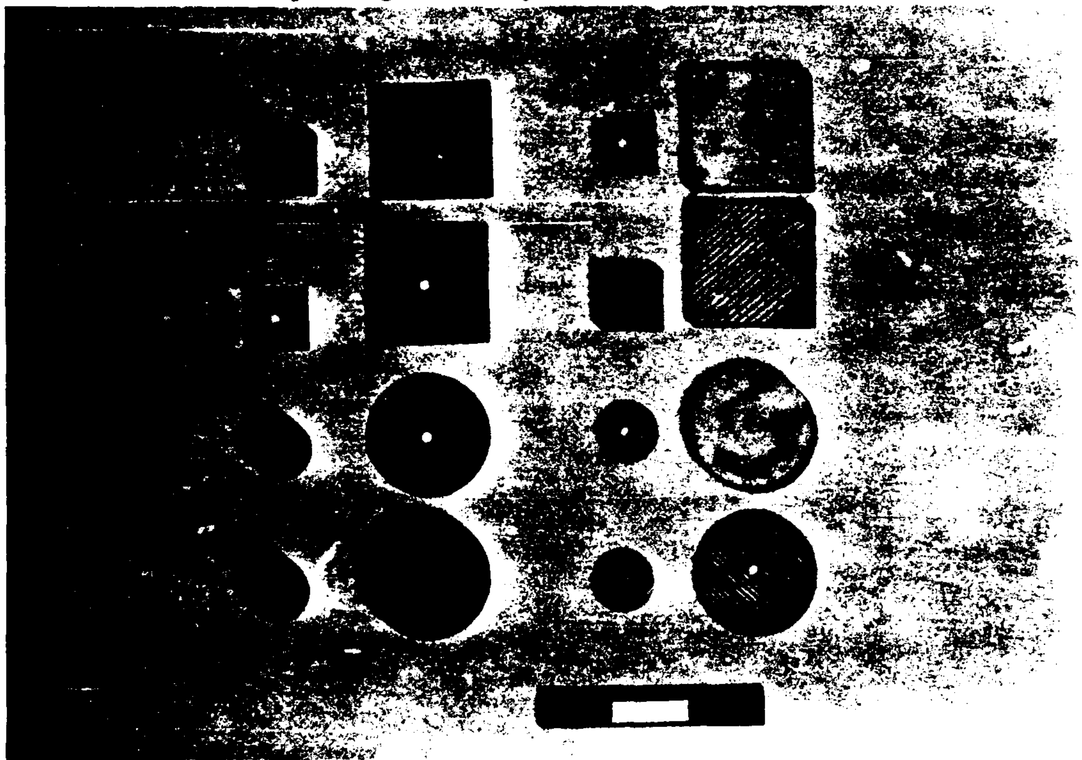
to 3) were taken into account.

3.2.4. FREE, DICHOTOMIC AND MULTIPLICATIVE CLASSIFICATIONS. LEVEL 2 : 6 CRITERIA OF DICHOTOMY (Botson and Deliège, 1976) (Experiment 1 : 9-10 y.o.; 14-15 y.o.)

Material :

16 geometrical forms. The characteristics of the elements were determinated as a function of 6 criteria of dichotomy : round/square; blue/yellow; large/small; thin/thick; pierced/whole; striped/stripeless.

There were always 8 elements for each component of the corresponding dichotomy.



Procedure, instructions and treatment of data were similar to those which were used for the level 1 classifications.

But, with this second material, the subject could carry out 6 different dichotomies and 15 different multiplicative classifications. So, he/she was asked to modify his/her dichotomy (or multiplicative classification) as many times as he/she could. The experimenter stopped requesting modifications when the subject had made 3 sucessive mistakes or had repeated 3 times in a row a given dichotomy (or multiplicative classification) he/she had already carried out, or when he/she had not produced any new solution for 3 minutes. To avoid memory problems, subject was given a photography of each classification he/she had already made.

Performances, procedures employed by the subject and his/her justifications were recorded.

3.2.5. INCLUSION QUANTIFICATION (Piaget and Inhelder, 1967) (Experiment 1 : 5-6 y.o.; 9-10 y.o.)

Material :
7 paper disks (3.5 cm Ø) : 5 blue and 2 yellow.

Procedure :
- The disks were disposed in line.
- Inclusion question : "You see, these are all paper disks,there are some yellow and some blue disks. Could you tell me if there are more paper disks or more blue disks".
- The subject was requested to justify his/her answer.

Treatment of data :
Only the subjects who gave the correct response and who could justified it, were considered as grasping the notion of inclusion.

3.2.6. PERMUTATIONS (Piaget) (Experiment 1 : adolescents and adults)

Material:
4 disks : 1 blue, 1 red, 1 yellow and 1 green.

Procedure:
a) Three disks were placed in line in front of the subject.
- The subject was asked to find the number of permutations which were possible with 3 disks and to tell how he/she had found this number.

Instructions :
1."How many different arrangements in line can you do with these 3 disks ?"
2."How did you find this number ?"
- Afterwards, the subject was asked to write the different permutations on paper.

b) The subject had to find and justify the number of permutations with 4 disks and finally, with 5 disks.

- Numbers given and their justifications were recorded.

Treatment of data :
Subjects were put into 4 categories, the performance criteria for being put in Cat. 4, presumably showing higher cognitive level that those for the other categories.
Cat. 1 : Subjects did not know the permutation computation principle and did not apply a systematic procedure to execute

permutations.

Cat. 2 : Subjects did not know the permutation computation principle and adopted a systematic procedure to execute permutations, but not to the totality of them.

Cat. 3 : Subjects did not know the permutation computation principle, but adopted a systematic procedure to execute the totality of permutations.

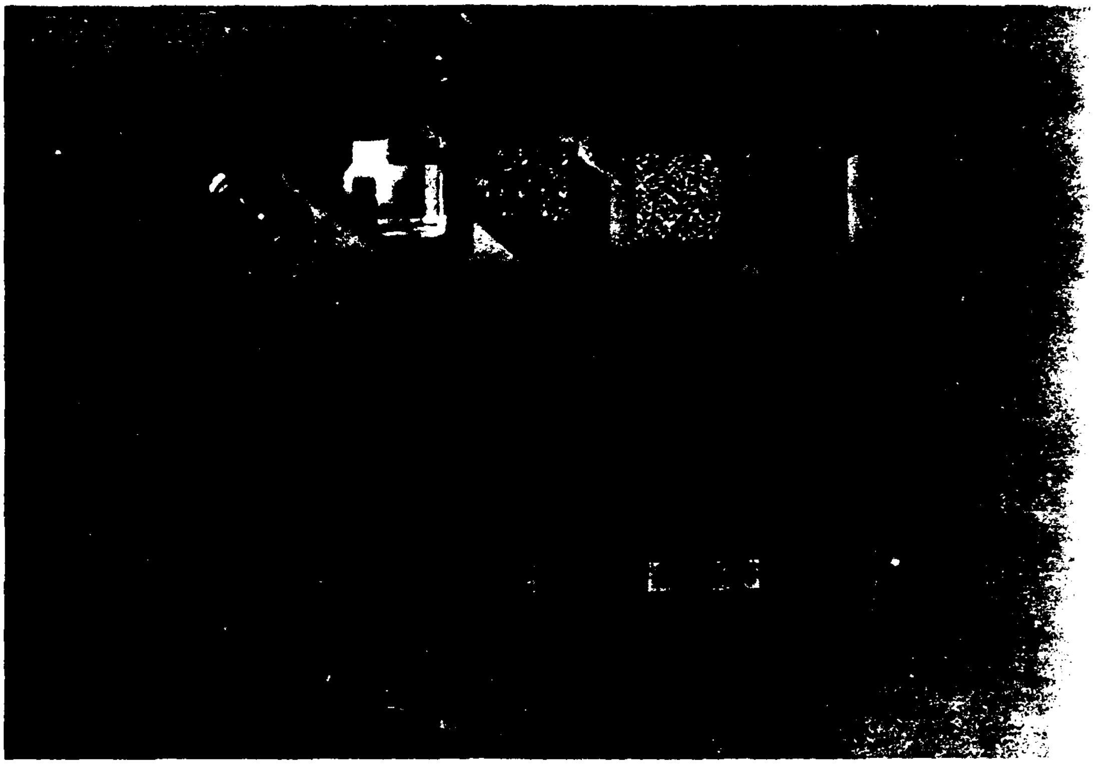
Cat. 4 : Subject knew the permutation computation principle and systematically executed the totality of permutations.

3.2.7. PERCEPTUAL SERIAL CLASSIFICATION (Botson and Deliège,1976) (Experiment 1 : 5-6 y.o.; 9-10 y.o.)

In this type of serial classification, the perceptual cues correspond to the logic of the system.

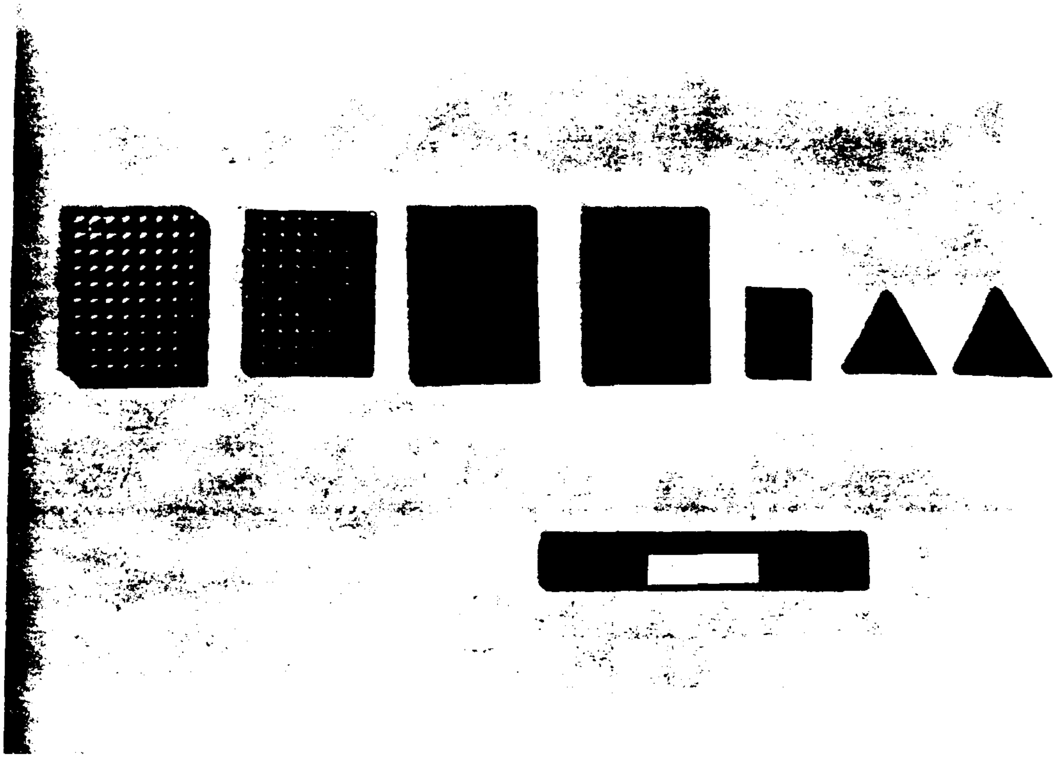
The task was composed of 4 items (the first, was a trainingg item). Each series could be dichotomized at each point according to the following properties.

Training item :



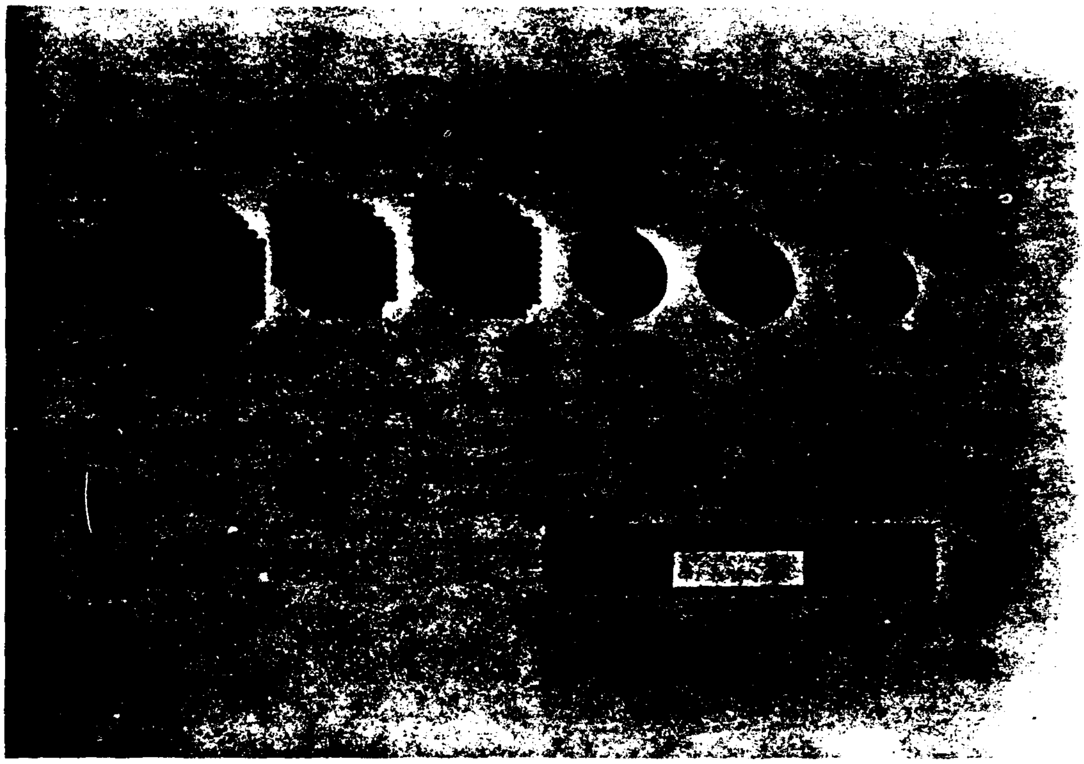
	Form	Texture	volume	color
spheric	angular	angular	angular	angular
smooth	smooth	rough	rough	rough
thick	thick	thick	thin	thin
colorless	colorless	colorless	colorless	colored

<u>Item 1</u> :



Thick / thin
Rough / Smooth
Red / Blue
Large / Small
Rectangular / Triangular
Opaque / Transparent

Item 2 :



Thick / Thin
Pierced / Whole
Square / Round
Red / Yellow
Rough / Smooth

Item 3 :

Colored / Colorless
Angular / Round
Volume / Flat
Whole / Pierced

Procedure :

For each item, the subject was presented with an array of objects varying along several dimensions. His/her task was to set in order the objects in such a way that at any point, the series could be dichotomically cut, with the objects on one side sharing a common property, but lacking an additional one shared by the objects on the other side.

a) Building the series :

Instructions :

"Here are the objects you will order in a row, one after the other, but paying attention to the sequence in which you do it. You choose first, the one that is different from all the others for whatever reason." "Then, you choose another one so that the first two go together and are different from all the ones left for whatever reason.""You choose another one so that the first three go together

and are different from all the ones left for whatever reason". Etc...

b) Justifying the order :

- After the construction of each series the subject was asked to justify each dichotomy.

Instructions :

"Tell me what makes the first object different from all the others; tell me what makes the first two objects different from all the others; etc..."

- If a series was incorrect, the experimenter corrected it and the subject was asked to justify each dichotomy again. If he/she could not do it, correct justifications were given by the experimenter to the subject.
- For each item, the series constructed by the subject and all justifications he/she proposed were observed and recorded by the experimenter.

Treatment of data.

An item was correct if the series and all the justifications given by the subject were correct. For each subject, the number of correct items was taken into account (from 0 to 3).

3.2.8. NON-PERCEPTUAL SERIAL CLASSIFICATION

(Botson and Deliège, 1976)
(Experiment 1 and 2 : adolescents and adults)

In this type of serial classifications, the perceptual cues conflict with the logical reasoning, though the general principles were the same as in perceptual serial classifications described above. The task was composed of 8 items (first and second are training items).

Materials :

On the pictures of the second training item and of the 6 test-items, the series to be completed is represented above the white separation line, the multiple choice display appears below this line and the appropriate object is placed on the separation line.

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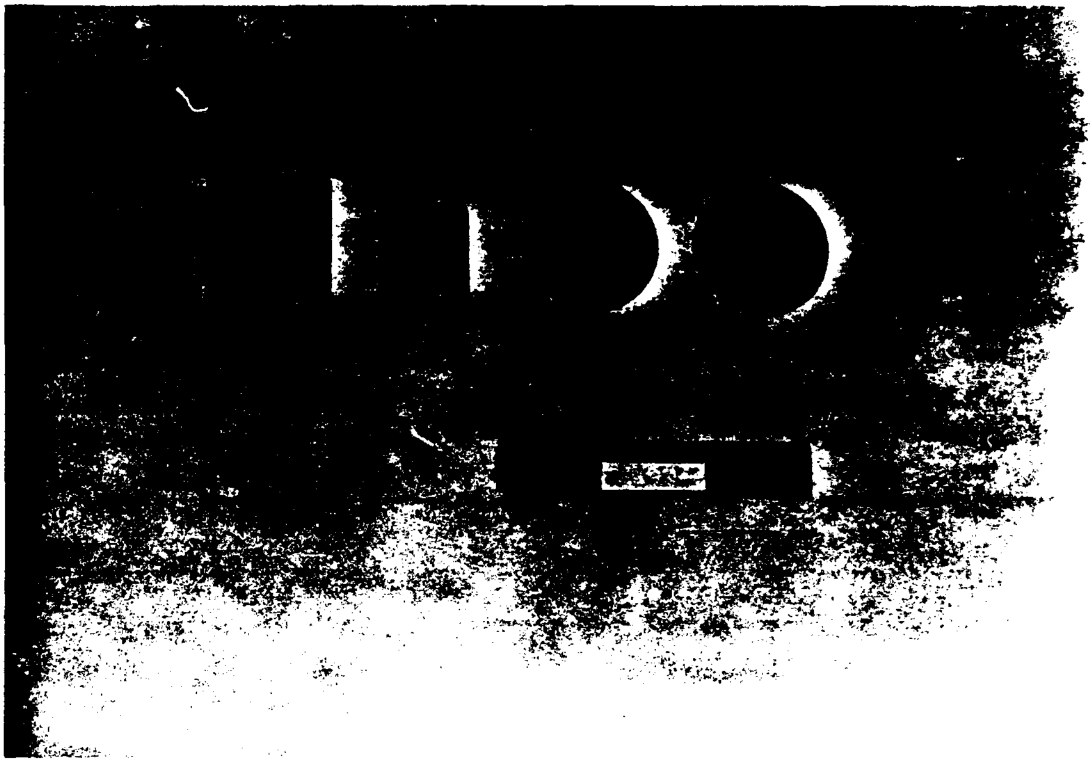
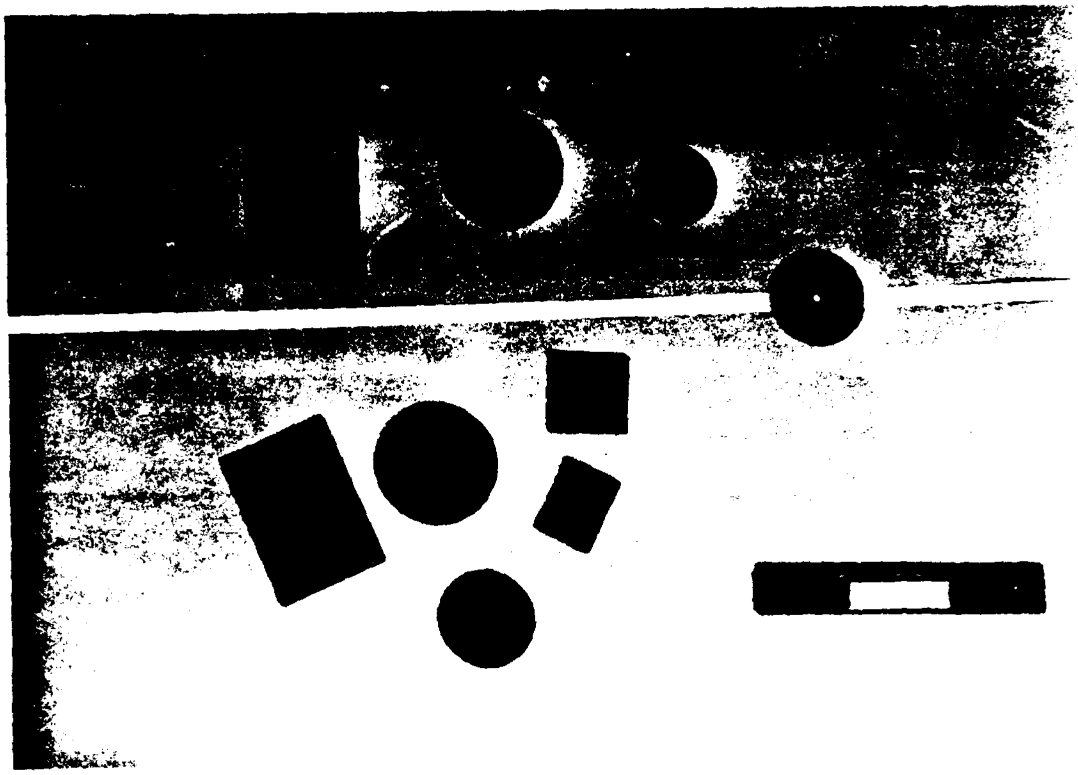
Training item 1 :



blue / red
square / round
smooth / rough

/ (

Training item 2 :



Square / round
Red / blue
(Whole / pierced)

The correct element wich complety the series is round, blue and pierced. The characteristic wich differentiates this element from the other ones is the fact that it is pierced (the 3 other elements are whole).

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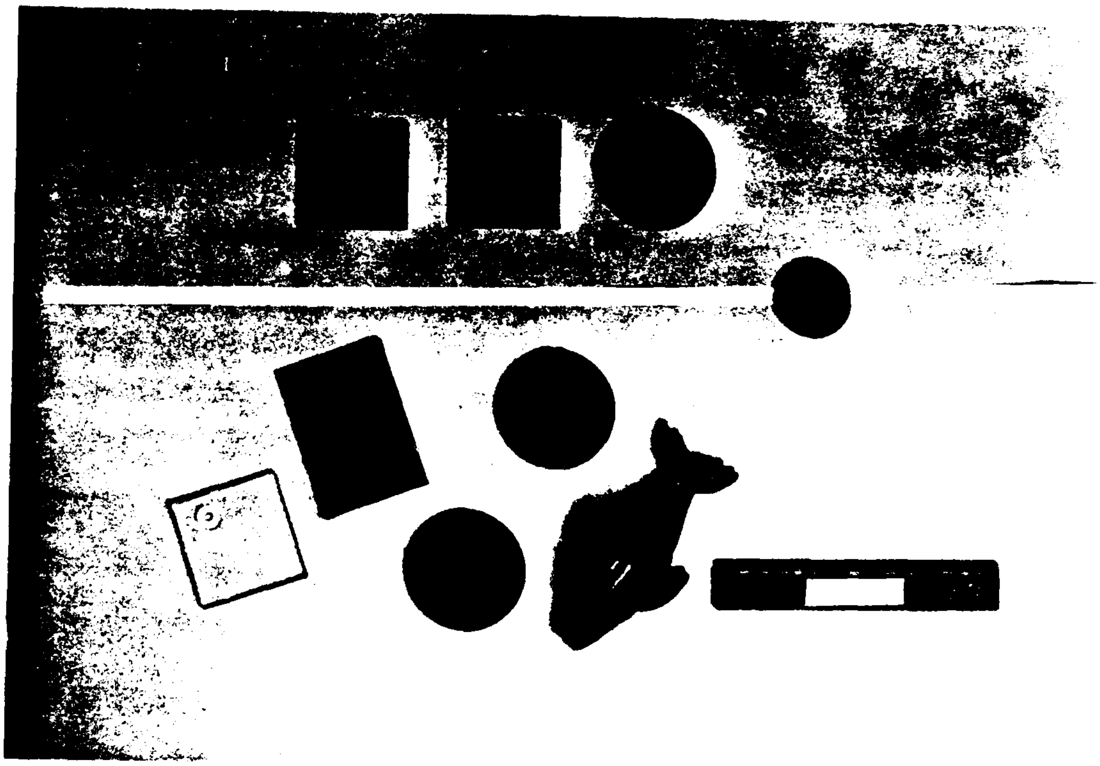
item 1 :



Blue / red
Square / round
(Large / small)

The correct element is red, round and small (all the other elements of the series are large).

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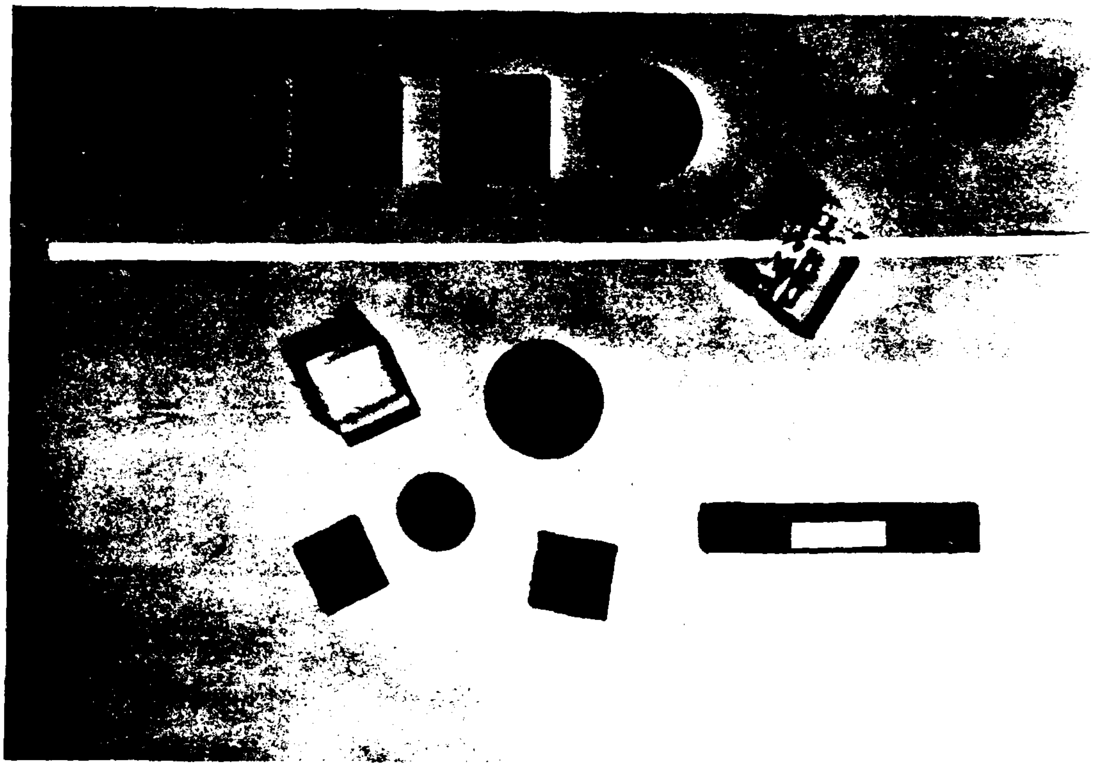
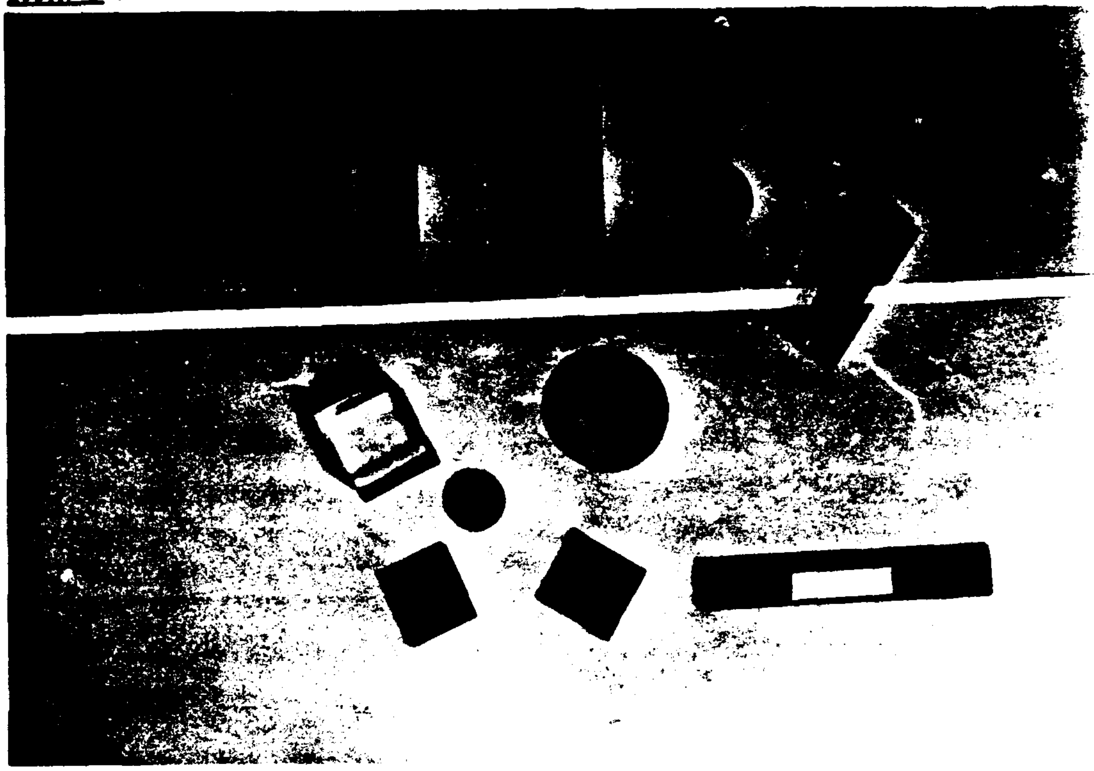
Item 2 :



Opaque / transparent
Rectangular / Round
(Flat / Volume)

The correct element is transparent, round and it is a volume

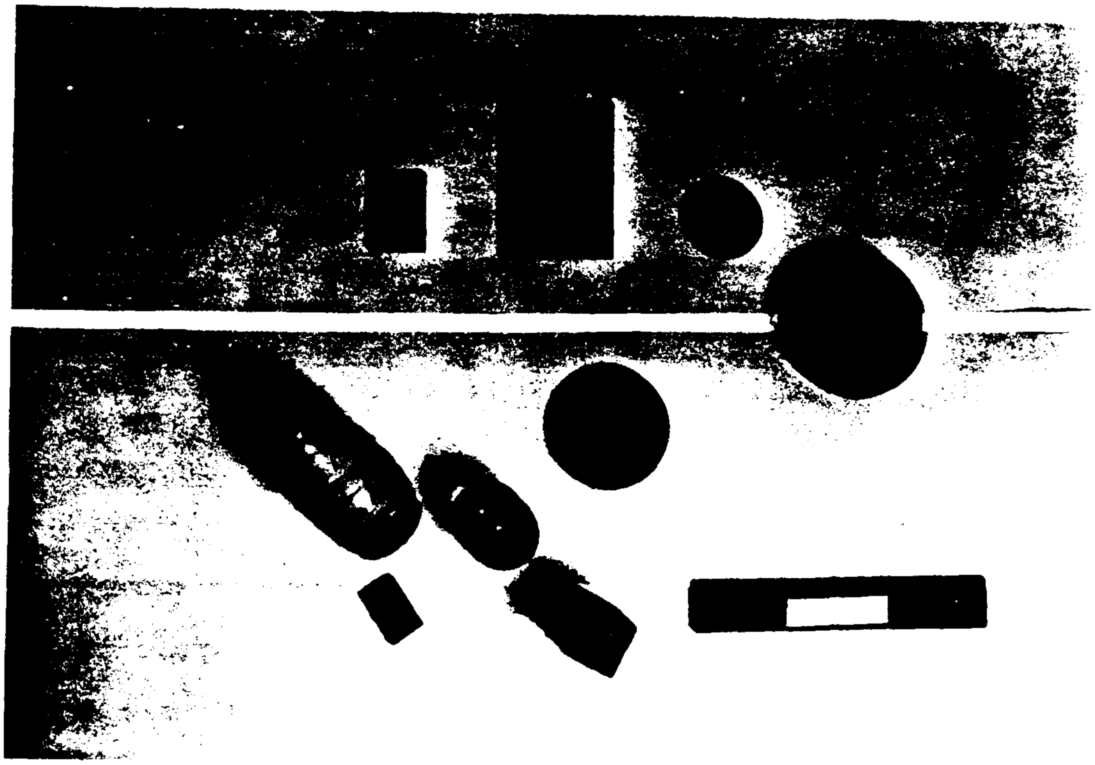
Item 3 :



Blue / Red
Rectangular / Round
(Flat / volume)

The correct element is red round and it is a volume (the other elements of the series are flat).

Item 4 :



Opaque / Transparent
Rectangular / Round
(Thin / Thick)

The correct element is transparent, round and thick (the other elements of the series are thin).

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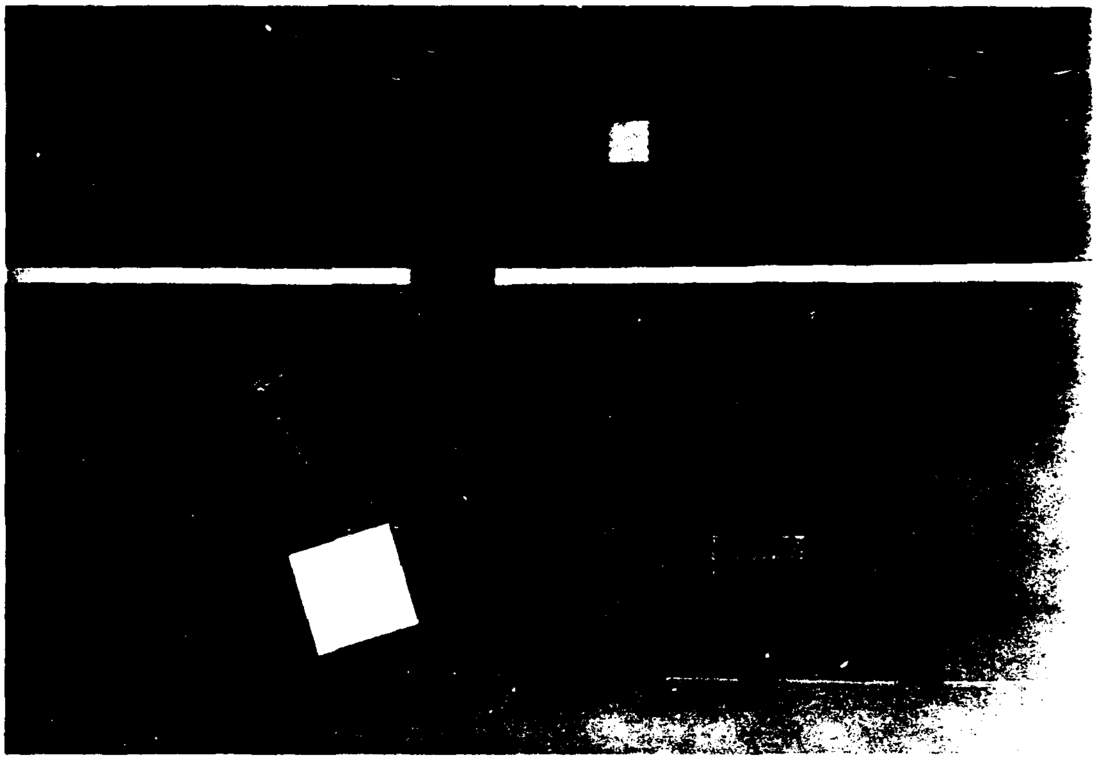
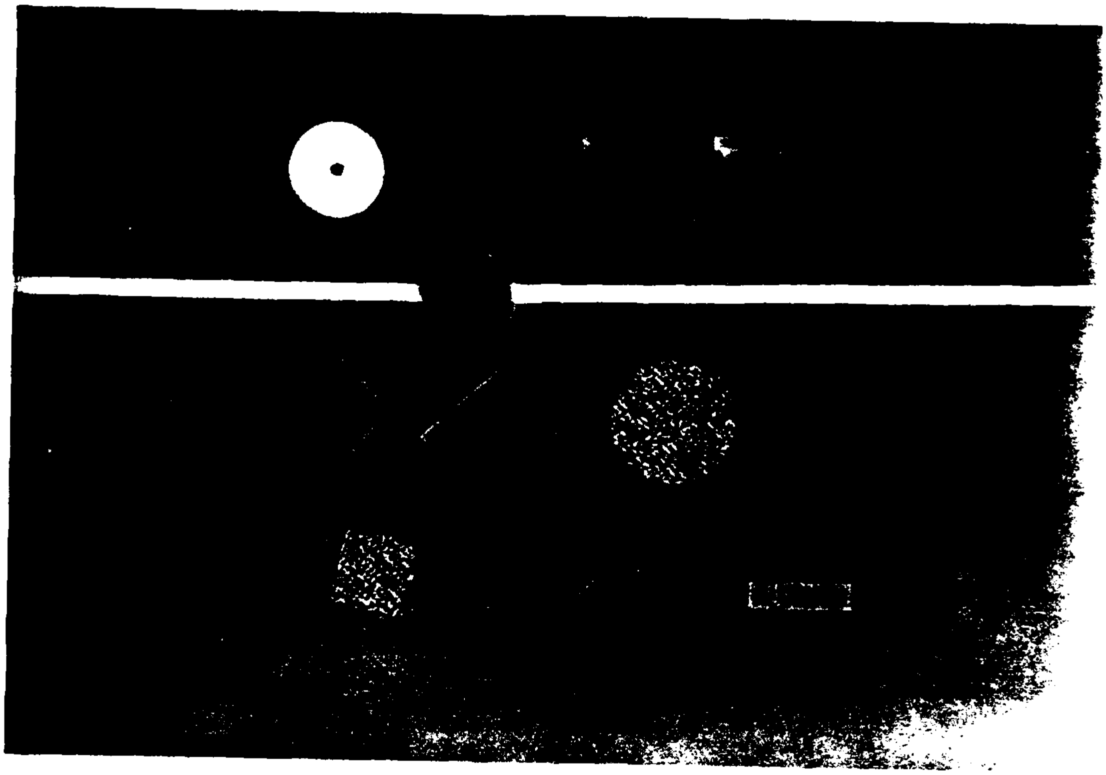
<u>item 5</u> :



Round / angular
Yellow / White
Opaque Transparent

The element wich must be inserted into the series is angular, yellow and opaque.

Item 6 :



Pierced / whole
Round / Angular
Opaque / Transparent
Smooth / Rough

The element wich must be inserted into the series is round, whole, opaque and smooth.

Procedure:

a) First training item :

Subject was presented with an array of 4 objects that varied along several dimensions. His/her task was to set in order the objects in such a way that at any point, the series could be dichotomically cut, with objects on one side sharing a common property, but lacking an additional property shared by the objects on the other side.

Instructions:

"These elements are all unlike each other. You will set them in an order that I shall explain to you. You choose first, the element that is different from all the others on one of its characteristics..., you

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choose the second one so that the first two share a common property which opposes them to all the others..., you choose the third one so that the first three share a common property which opposes them to all the others, etc...You will verify that, at any point, the arrangement is correct before you say that you have finished it."

b) Second training item :
- On a first occasion, the subject was presented with an array of three objects and his/her task was to set in order these objects (as in the first training item).
- The second time, the subject was presented with 6 other objects and his/her task was to select the object that completes the series adequately.

Instuction :
"Now you will choose among these elements one which can be placed at the end of the row, so that the series remains correct. It is necessary that no matter where we cut, we will still be able to find a difference between all the elements at the left, and all those at the right".

c) Item 1 to item 6.
Subject's task was to complete the series by inserting, at a given point, the appropriate object (at the end of the series for items 1 to 4, and between 2 objects for items 5 and 6).

Instructions :
Similar to those given for the second training item.
- For each item, after the object was chosen, the subject was asked to justify all the dichotomies of the series.
- When the chosen object was not appropriate, the experimenter gave the subject the appropriate one and explained all the dichotomies.
- For each item, the chosen object and justifications were recorded.

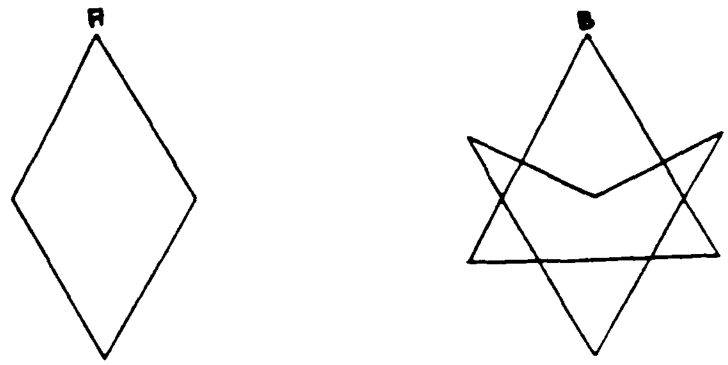
Treatment of data :
An item was correct if the chosen object and the justifications given by the subject were correct.
For each subject, the number of correct items was taken into account (from 0 to 6).

3.2.9. "GROUP EMBEDDED FIGURES TEST" (GEFT) : FIELD-DEPENDENT AND FIELD-INDEPENDENT COGNITIVE STYLES
(Experiments 1 and 2 : adolescents and adults)

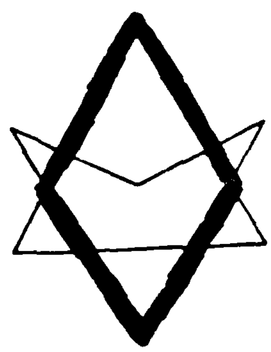
- The french version of the "Group Embedded Figures Test" (OLTMAN, RASKIN and WITKIN, 1971) was employed ("Test des Figures encastrées", published by : Les Editions du Centre de Psychologie Appliquée, Paris, France, 1985).

- This test consisted of complex figures in which the subject had to recognize a simple figure. When the subject had found it, he/she traced its outlines with precision and as fast as possible. There were three parts : the first part was composed of 7 items; it constituted a training exercise. Each of the others two parts were composed of 9 items.
  The time limit was, respectively, for the 3 parts, of 2, 5 and 5 minutes.

- In the example presented below, the subject had to recognize the simple figure A in the complex figure B.



Solution :



Treatment of data :

Only the 18 items proposed in the last two parts of the test were taken into account.

The number of simple figures recognized and traced with precision in the time limits was computed for each subjects (the degree of field-independence increases as a function of the number of correct items).

3.2.10. TASK OF KAUFMANN (1979) (Experiment 3 : adults)

Material, procedure and instructions :

Subjects received a little book with a problem on each page. They had a paper and a pencil at their disposal.

They were presented with the following instructions :

"You will now be required to solve some practical problems. Imagine that you are working as a clerk in a shop, and a customer asks for a certain amount of flour. Unfortunately, your scales are not working. However, there are some containers available, each of which holds a certain amount of flour. By way of these you will be able to find the amount required.
Let us have a look at an example which demonstrates what the task is about and how it is to be solved : you are to get 20 grams. You have one container available that holds 29 grams and another one that holds 3 grams. How to get 20 grams ?
Solution : you fill up the 29 grams container and then you pour 3 grams into the other container 3 times. As you see, we now get : 29 - 3 = 26 - 3 = 23 - 3 = 20 grams and we have solved the problem. Now there are 20 grams left in the large container. Agree ? Are you sure you have understood what the task is about ? In the following you will get several such tasks to solve".

The problems, presented at interval of 3 minutes, and their possible solutions are given in Table 0.3.

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PROBLEMS	CONTAINER GIVEN (quantity in grams) A	B	C	TO GET	SOLUTION
Example	29	3		20	a. A - 3B
1	21	127	3	100	a. B - A -2C b. B - 9C c. B - 2A + 5C
2	14	163	25	99	a. B - A - 2C
3	18	43	10	5	a. B - A - 2C
4	9	42	6	21	a. B - A - 2C b. B+ A - 5C c. A + 2C d. 3A - C e. B + C -3A
5	20	59	4	31	a. B - A - 2C b. B - 7C
6	18	48	4	22	a. B - A - 2C b. A + C
7	28	76	3	25	a. A - C

Table 0.3. : Problems and solutions, as proposed in the Task of Kaufmann

The "Example" problem was for illustrative purposes. If the jars, in the order written, are labeled with the letters A, B, C, respectively, then the test-problems (1 to 6) are all solvable by the formula B - A - 2C. Problem 7 does not fit this formula. While it is possible to solve all the test-problems by the same formula, several other solutions to these problems are also possible. Some of them are simpler, some are about the same complexity, and some are more complicated that the B - A - 2C procedure.

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Treatment of data :

Subjects were put into 2 categories :
In the category "Assimilator" were put subjects who employed the standard principle throughout the 6 test-problems

In the category "Explorer" were put subjects who employed one or more deviant solution -alternatives.

3.3. GENERAL PROCEDURE AND SYNTHESIS OF THE METHODOLOGICAL CHARACTERISTICS SPECIFIC TO EACH EXPERIMENT

Each subject was individually submitted first to several sessions, of 50 trials each, on the Visual Matrix task.

Subjects of each age group (or of each type of educational background) were randomly distributed into several experimental groups. These differed according to the type of matrix proposed at each session.

After completing the Visual Matrix task, subjects were individually submitted to "cognitive" tasks. Afterwards, subjects who wanted it, were informed about the purpose of the experiments and were given an answer to any question they wished to ask.

The methodological characteristics specific to each experiment are presented in Table 0.4., that is reproduced on a separated sheet to help reading in following chapters.

	I. Developmental approach to behavioral variability				II. Effect of a variability training on the subjects' adaptation in a new situation. Variability and educational background							
	EXPERIMENT 1				EXPERIMENT 2		EXPERIMENT 3					
SUBJECTS												
- Age	5-6 y.o.	9-10 y.o.	14-15 y.o.	18-24 y.o.	14-15 y.o.	18-24 y.o.	18-27 y.o.					
- Number	79	91	98	100	31	22	69					
- Educational background	Nursery School	Elementary School	General Secondary School	University	Technical Secondary School	Industrial Training Center : Technical Study	Technical study			Non-technical study		
							Low level	medium level	upper level	low level	medium level	upper level
EXPERIMENTAL GROUPS (They differed as a function of type of matrix proposed at each session	1. NNN 2. NRN 3. NDN 4. DRN 5. RDN				1. NNNCN 2. NDD10CN		1. NNNC 2. NDD10C					
COGNITIVE TASKS												
- Simple seriation	x											
- Multiplicative seriation		x										
- Classification : Level 1	x	x										
- Classification : Level 2		x	x									
- Inclusion quantification	x	x										
- Permutations			x	x								
- Perceptual serial classification	x	x										
- Non-perceptual serial classification			x	x	x	x						
- GEFT (Field dependence/ independence			x	x	x	x						
- Kaufmann's task ("Assimilator/Explorer")							x					

Table 0.4 : Methodological characteristics specific to each experiment (x : indicates cognitive tasks used in each experiment and in each age group)

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CHAPTER 4

DEVELOPMENTAL APPROACH TO BEHAVIORAL VARIABILITY

- EXPERIMENT 1 -

4.1. AIMS OF EXPERIMENT 1

The following questions were considered in a developmental perspective :

1. Does contingent reinforcement produce stereotypy, even when this last one is not required ?

2. What is the role of the information given by the environment ? What is the role of visual cues ? Do they influence the sequence form ?

3. Is it possible to induce behavioral variability ?

4. Which role is played by the individuals' experimental history, depending upon the situations they have been experiencing ?

5. Are there relations between the subjects' cognitive capacities, their cognitive style (field dependence / independence) and their performance and variability at the Visual Matrix task ?

4.2. METHOD

4.2.1. SUBJECTS

Subjects whose data could not be entirely used (absence from school or recording errors) were excluded from an initial sample of 100 subjects in each age group. Finally, 368 subjects were selected and distributed into four age groups :

1. Nursery School children (n = 79; 43 girls and 36 boys) ranged in age from 4-1 to 5-11 with a mean of 5-5 years of age.
2. Elementary School children - 4th grade - (n = 91; 45 girls and 46 boys) ranged in age from 9-2 to 11 with a mean of 9-9 years of age.
3. General Secondary School adolescents - 3th grade - (no Technical School subjects were included) (n = 98; 59 girls and 39 boys) ranged in age from 13-1 to 15-8 with a mean of 14-8 years of age.
4. Adult subjects (studen , all departments, at the University of Liège) (n = 100; 39 females and 61 males) ranged in age from 18-3 to 24-7 with a mean of 20-1 years of age.

Subjects of the first three age groups were issued from the community run schools of the city of Liège.

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4.2.2. MATERIALS AND PROCEDURE

- Visual Matrix Task :

Three different matrix types were used : (see list of matrix types, Table 0.1, p. 80)

- Normal matrix (N),
- Random matrix (R),
- Normal matrix with differential reinforcement (D)

Subjects of each age group were randomly distributed into five experimental groups and they were individually submitted to three sessions of 50 trials each, in a room of their school (a period of 24 hours was allowed to elapse between two consecutive sessions).

EXPERIMENTAL GROUPS	SESSION 1	SESSION 2	SESSION 3
1	N	N	N
2	N	R	N
3	N	D	N
4	D	R	N
5	R	D	N

The subjects of our sample were distributed into the 5 experimental groups as showed in the Table 1.1.

AGE	5 - 6 YEARS OLD					
GROUPS	NNN	NRN	NDN	DRN	RDN	TOTAL
FEMALES	8	12	8	6	9	43
MALES	7	6	8	7	8	36
TOTAL	15	18	16	13	17	79

AGE	9 - 10 YEARS OLD					
GROUPS	NNN	NRN	NDN	DRN	RDN	TOTAL
FEMALES	10	10	9	7	9	45
MALES	10	8	10	10	8	46
TOTAL	20	18	19	17	17	91

AGE	14 - 15 YEARS OLD					
GROUPS	NNN	NRN	NDN	DRN	RDN	TOTAL
FEMALES	12	14	12	9	12	59
MALES	5	6	7	12	9	39
TOTAL	17	20	19	21	21	98

AGE	ADULTS					
GROUPS	NNN	NRN	NDN	DRN	RDN	TOTAL
FEMALES	8	10	6	7	8	39
MALES	13	10	14	13	11	61
TOTAL	21	20	20	20	19	100

Table 1.1 : Subjects' distributions as a function of experimental group and of sex, in each age group.

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- Cognitive tasks :

The specific tasks used in each group can be found in Table 0.4., p. 111.

4.3. RESULTS

4.3.1. VISUAL MATRIX TASK

The indices selected to provide optimal information about performance and behavioral variability in the Visual Matrix Task have been defined pp (indices n° 1 to n° 8).

Two supplementary indices were calculated for this experiment :

- The mean time of realization of one sequence : **MTR**
  It is the mean time for completing one correct or incorrect sequence. A sequence begins with the first push and ends with the last push on one response-button.
- The mean time of latency : **MTL**
  It is the time between the moment when a first lamp on the Visual Matrix is lit on and the first push on one response-button, that initiates a sequence.

Means and standard deviations for each index and for each experimental group, according to age and to session, can be found in Appendix 1, tables 1.2 to 1.11, pp 12-21.

4.3.1.1. Effects of age and of session order in each experimental group :

- *Student T-tests for related samples were used to compare the values of each index, in the 3 sessions in each experimental group and in each age group (see Tables 1.23 to 1.42 in Appendix 1, pp 28-47).*
- *For each index, One-Way ANOVA (F) and Newman-Keuls procedure (NK) were used to compare the four age groups, in each session of each experimental group (see Tables 1.53 to 1.62, in Appendix 1, pp 58-67).*

- Experimental group NNN

Figure 1.1. (p. 119) presents, for each index, mean values as a function of session, for each age group, in the group NNN.

- *Performance* :
  In each age group, there is an increase of the %C.S. from the first to the third session. The 5-6 years old (y.o.) subjects obtain the lowest % C.S. In each session (significantly different only for the first session). Their performance is progressively approaching the performance of the other age groups. The latter have, at once, very high level of % CS (> 90%). (">" means "superior to"; "<" means "inferior to").

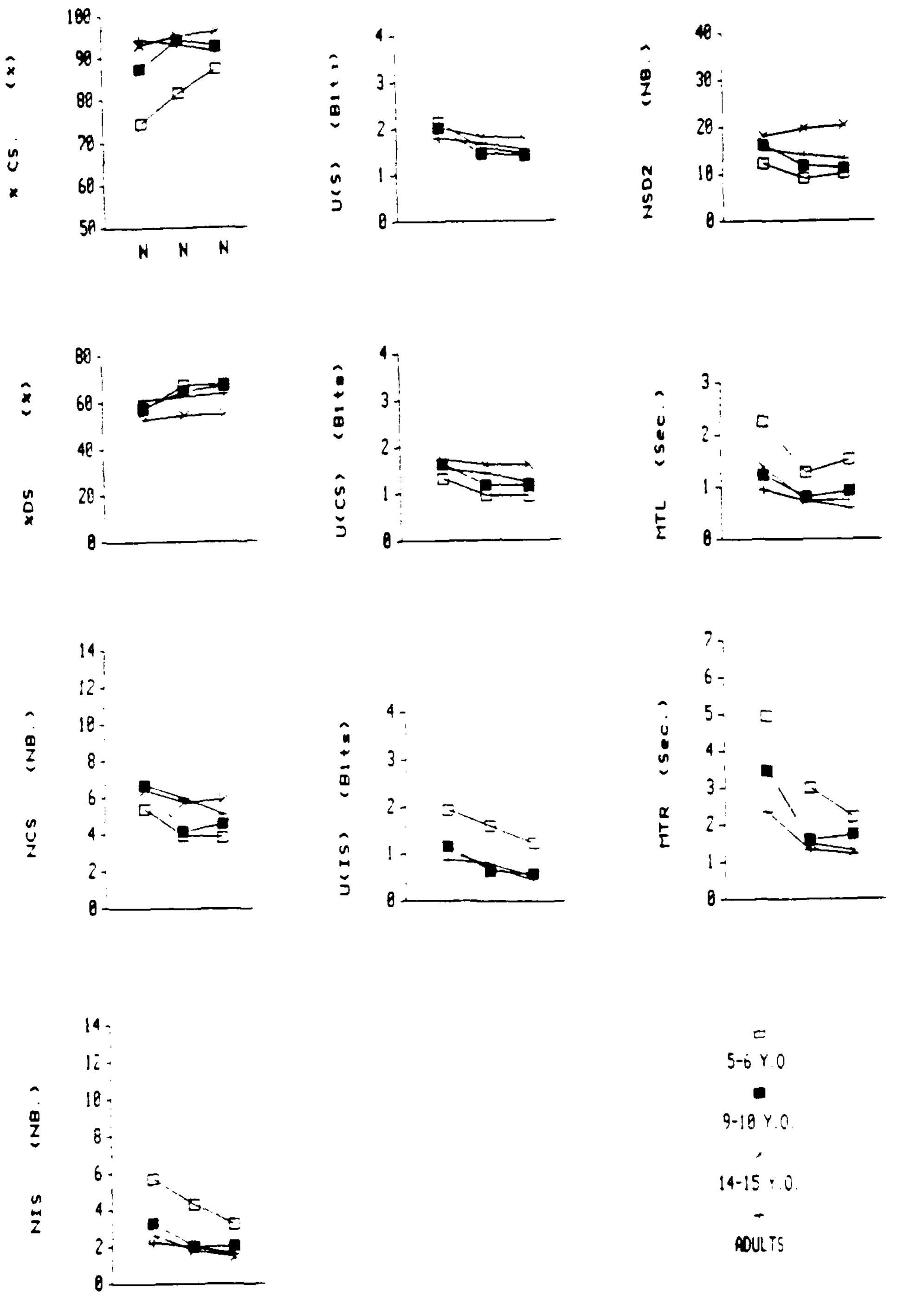

Fig. 1. 1. For each index, mean values as a function of session and for each age group, in the group NNN

73.

There is a concordance between results obtained on realization times and results on performance : MTR is significantly reduced between the first and the second session, for all the age groups. It is still decreased for the 5-6 y.o. during the last session. Generally, the youngests are the lowest and the adults, the fastest for MTR and MTL

- *Variability* :
  Parallel to the increase of performance, there is an increase of sequences stereotypy, as globally shown by the indexes that estimate the degree of sequences variability (see : %DS, NCS, NIS, U(S), U(CS) and U(IS) in Figure 1.1.). This is especially marked from the first to the second session and for the 5-6 and 9-10 y.o. There is no significant difference between age groups, if we look at the variability of correct sequences (NCS, U(CS)). But we find a slight tendency for the 5-6 y.o. to be more stereotyped and for the 14-15 y.o. to be more variable. The youngest subjects use, on the contrary, more incorrect sequences and are here significantly more variable than the other age groups.

- Experimental group NRN

Figure 1.2. (p. 121) presents, for each index, mean values as a function of session, for each age group, in the group NRN.

- *Performance* :
  The matrix R produces a significant decrease of the performance in all the age groups (see % CS). The % CS returns to its initial level during the last session, for the first three age groups. It rises slightly for the adults. The 5-6 y.o. constantly obtain the lowest % CS . The Elementary School subjects seem to be the most disturbed by the incoherence of visual cues in R : they show the most important decrease of the % CS and they attain a level similar to the one obtained by the youngest subjects. Realization times are also modified by R : they increase from the first to the second session, except for the 5-6 y.o. whose MTR stays at the same high level as in the first session. Afterwards, they are significantly reduced to a lower level than the one reached in the first session, again except for the 5-6 y.o. whose MTR remains high. Latencies are not so much influenced by R, except for the youngests whose MTL constantly stays at high levels.

- *Variability* :
  For all age groups, the variability of incorrect sequences (U(IS) and NIS in figure 1.2., pp....) increases significantly with the matrix R. This is consistent with the decrease of the performance in R and explains, for a major part, the increase of general variability (U (S)) among the 5-6 y.o., the 9-10 y.o. and the adults (significant only for the first two age groups). Despite the higher variability of incorrect sequences, global variability (U(S) and % DS) remains stable among the 14-15 y.o. This can be explained by the slight increase of the correct sequences stereotypy in this age group, instead of the slight decrease of

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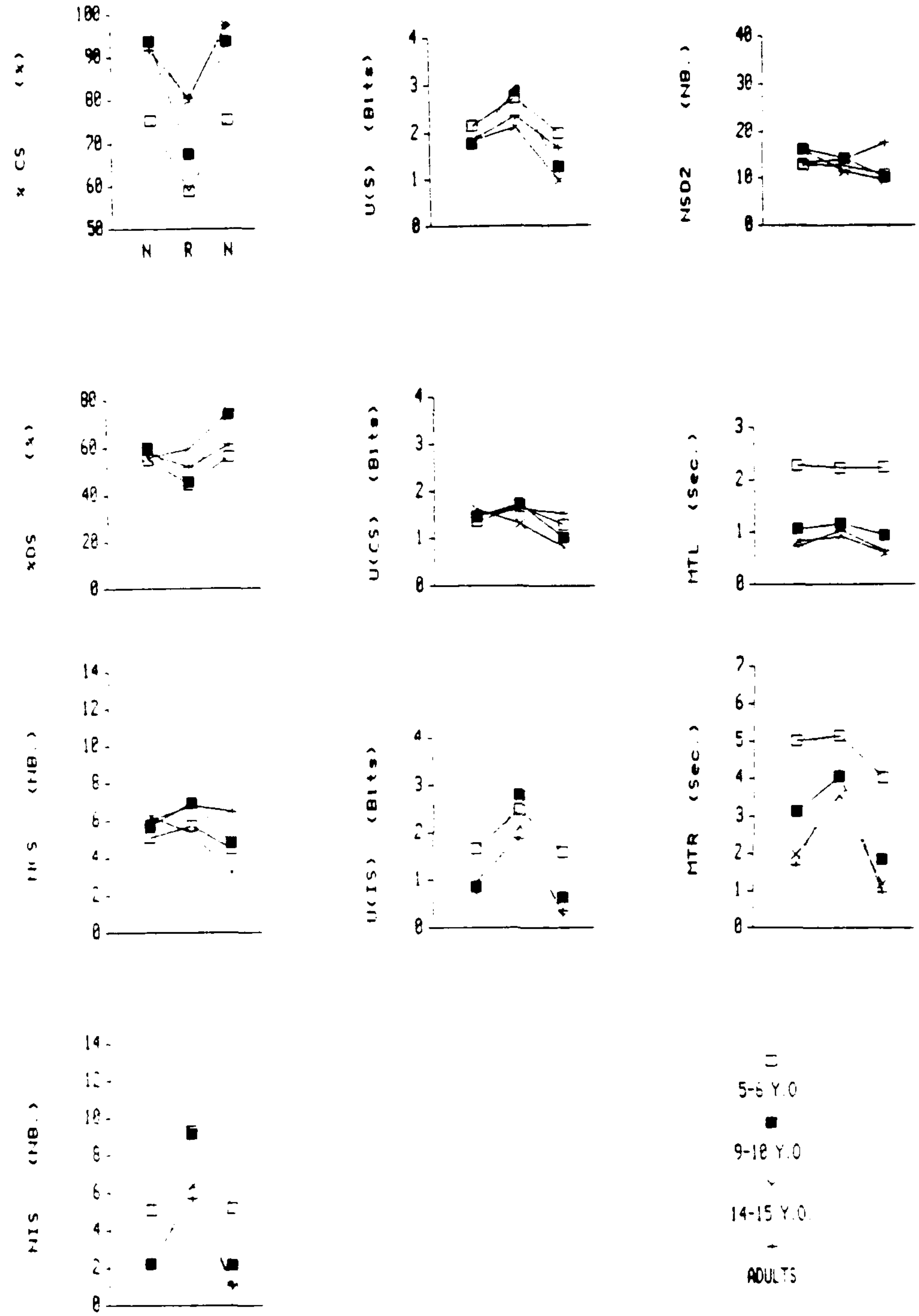

Fig. 1. 2. For each index, mean values as a function of session and for each age group, in the group NRN

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this feature in the other age groups. During the last session, the variability of incorrect sequences is significantly reduced for all the subjects, while the 5-6 y.o. maintain the highest level. The 9-10 y.o. and the 14-15 y.o. become more stereotyped than during the first session and reach the lowest levels for all the cues related to correct sequences variability.

- Experimental group NDN

Figure 1.3. (p. 123) presents, for each index, mean values as a function of session, for each age group, in the group NDN.

- *Performance* :

The requirement of variability in D does not stop the increase of CS %. Globally, subjects behave like in the first experimental group NNN, even if we observe differences between age groups during the second session. Indeed, the first two age groups do not increase their % CS as much as with N in second session and the two others reach a slightly higher level. But, we may suppose that the differences between age groups are due, at least in part, to slight differences in the sample of subjects.

We have taken here into account an index that corresponds to the number of reinforcement in the matrix D : the number of sequences differing from the two previous ones (NSD_2). It gives, in fact, the real performance of subjects with D and it allows to assess their adaptation to the variability requirements. During the second session, we observe a significant increase of NSD_2 for all the age groups, but the percentages of reinforcement (NSD_2 x 2) do not reach those obtained with the matrix N (% CS) in first session (32% < 81.5% for the 5-6 y.o.; 50.86% < 88 % for the 9-10 y.o.; 77.5% < 95.62% for the 14-15 y.o. and 75.46% < 91.57% for the 18-24 y.o.). The youngests have more difficulties to adapt themselves to the task in D. They are able to raise their variability but they do not reach a good performance. Two hypothesis can be proposed to explain this low performance : - either, they have not perceived the modification of contingencies and the increase of variability is only a by-product of the intermitence of reinforcement. Either they have perceived the modification of contingencies but they do not sufficiently master the functioning rules of the matrix task (notably the visual informations) to systematically vary their sequences. Results of an experiment carried out by BOULANGER (1986) lead us to reject the first hypothesis (we shall come back to this experiment subsequently) but present data are not enough to support the second one. After 3 sessions, each subject had been asked what he had done to succeed in the task and which functioning rules he had discovered in each session; however, most often, subjects confounded the 3 sessions or they did not recall what they had done in the first or

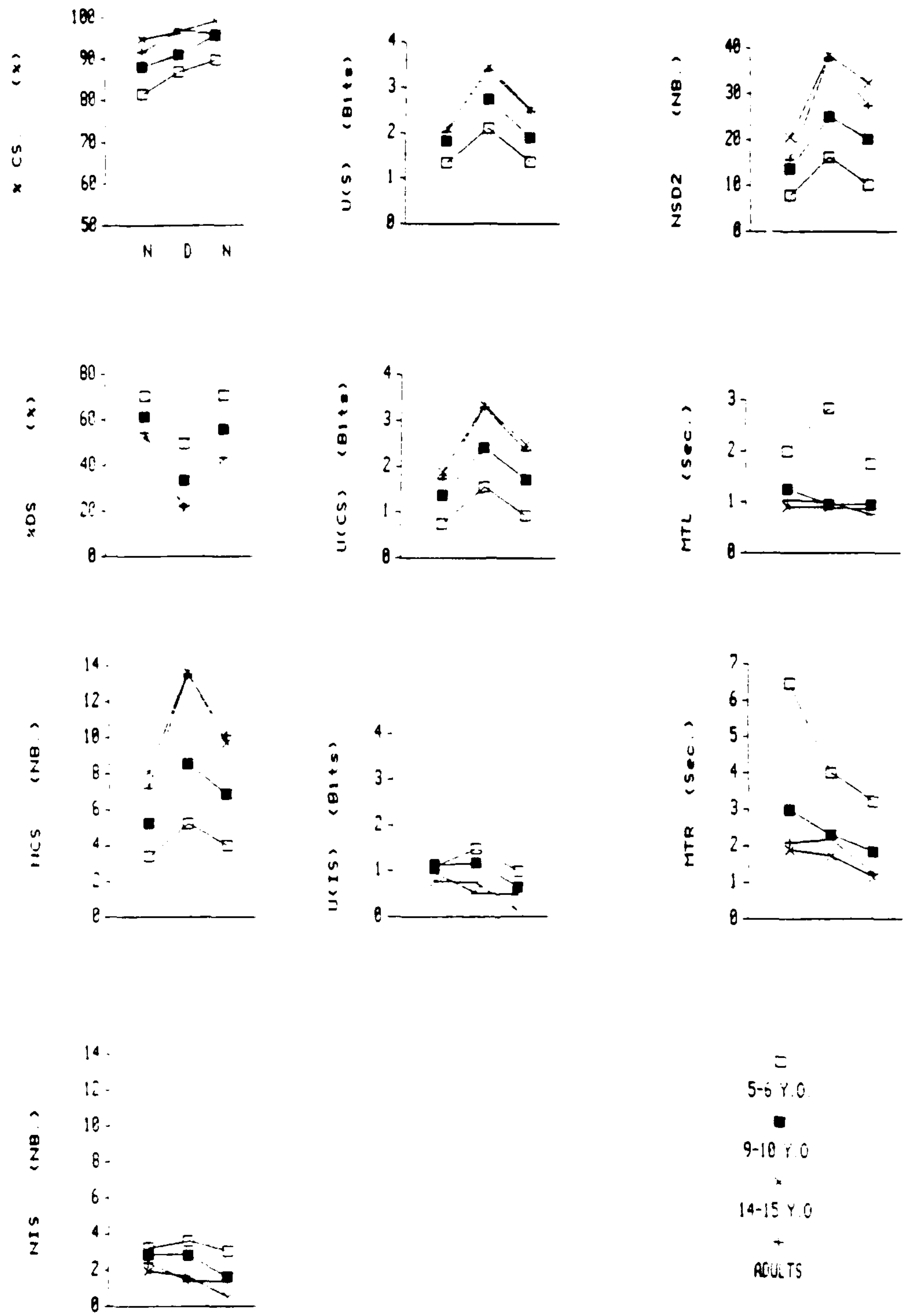

Fig. 1. 3. For each index, mean values as a function of session and for each age group, in the group NDN

second session. So, the responses obtained were unusable. (In other respects, to question the subjects after each session, was likely to influence the subjects behaviors in the ulterior sessions. It would be interesting to make a specific experiment in which the experimenter would observe and interact with each subject in order to gather informations about the subject's mastery of functioning rules). Adolescents have approximatively the same performance as adults and, they all show a good adaptation to the requirement of variability. Except for the 5-6 y.o., NSD_2 is higher in the third than in the first session, suggesting that these subjects were influenced by their earlier behavior in D. No inter-age groups difference does subsist here. Realization times are not significantly decreased during the second session, but they are during the last session. Times of latency are longer in D than in N for the 5-6 y.o.

- *Variability* :

Matrix D leads to a significant increase of general variability (U(S)). This increase is due to the increase of the variability of correct sequences (U(CS), NCS) for all age groups. The variability of incorrect sequences stays nearly stable except for adults. The 5-6 y.o. have a higher U(IS) than adults and adolescents and, like the 9-10 y.o., they produce more different incorrect sequences than other subjects. In each session, variability increases as a function of age. The 5-6 y.o. are more stereotyped. Behaviors of adolescents and of adults are comparable from this point of view. The matrix D influences the subsequent behaviors of adults and adolescents. As mentioned above, their NSD_2 is higher in the third than in the first session. They also produce more different correct sequences. U(S) and U(CS) are higher (significant only for adults).

- Experimental group DRN

Figure 1.4. (p. 125) presents, for each index, mean values as a function of session for each age group, in the group DRN.

- *Performance* :

- Matrix D : The % CS are similar, for all the age groups, to those obtained during the first session in the experimental group NNN. The number of reinforcements (NSD_2) increases as a function of age, with adolescents and adults reaching comparable levels of performance. The performance of the 9-10 y.o. is closer to the performance of the older subjects in D in first session than in D in second session (Experimental group NDN). For the youngests, the same comments as for D in NDN can be made (difficulties to meet the requirements of the task).

- Matrix R : Except for the 5-6 y.o., whose % CS stays stable, there is a decrease of this index in R (significant only for 9-10 y.o. and adults). The 9-10 y.o. again seem to be the most disrupted by the incoherence of

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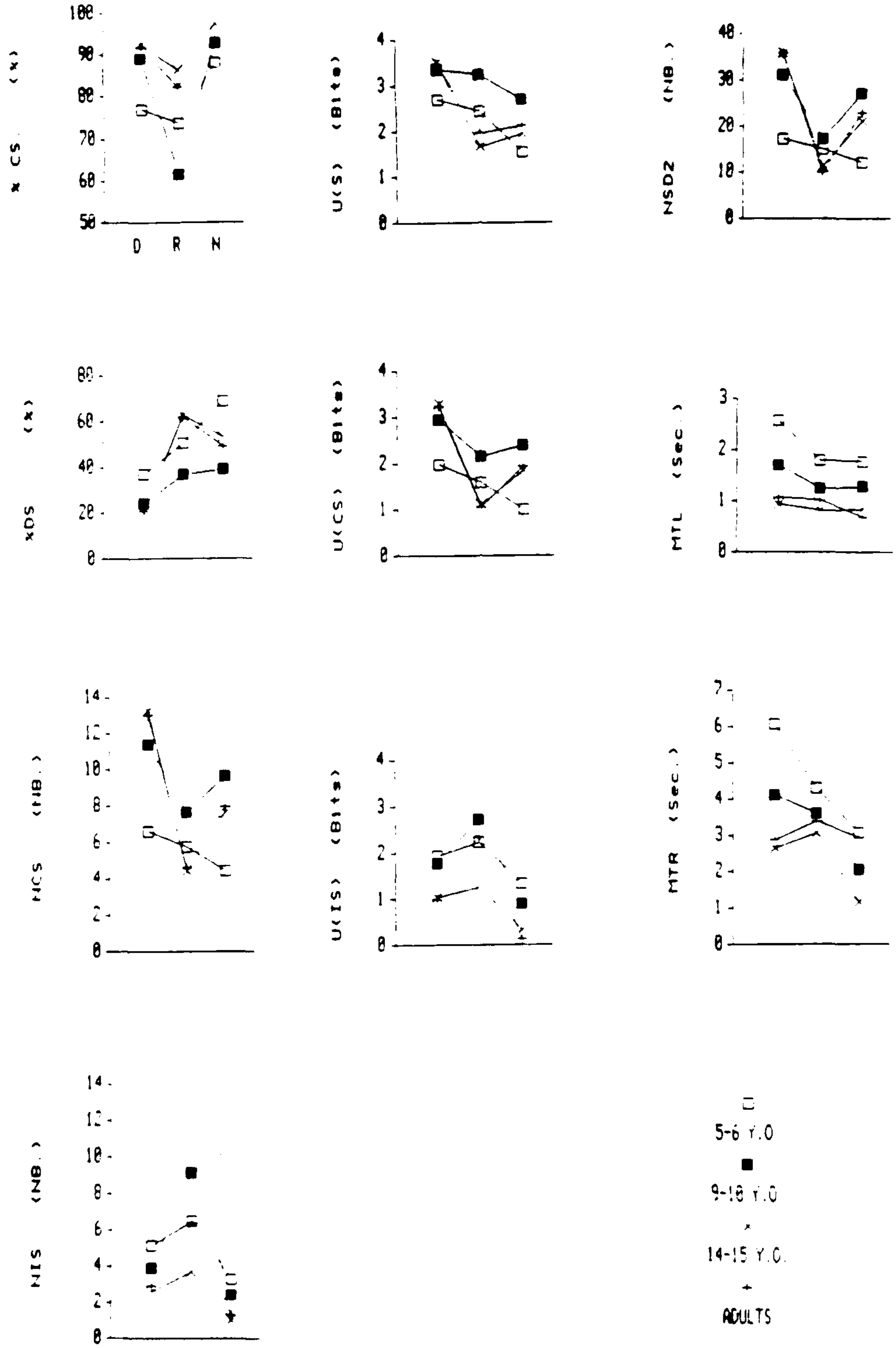

Fig. 1. 4. For each index, mean values as a function of session and for each age group, in the group DRN

visual cues (see NRN). They obtain fewer reinforcements than the 5-6 y.o. (but not significantly).

- Matrix N : The % CS is significantly increased in all the age groups. These percentages are higher than those observed during the first session (no significant for adults) and are similar to those of the third session in NNN. In D, realization times are reduced as a function of age, with the last two age groups reacting in the same way. The 5-6 y.o. complete the sequences more quickly during the second session. Their MTR is comparable to the one of the 9-10 y.o. The adolescents and adults do not behave very differently from each other, but adolescents have a slight tendency to be more rapid. In N, realization times are decreased for all the age groups. This index stays at a quite high level for adults, in comparison with the values it reaches during the third sessions of other experimental groups (significantly different from adolescents' MTR). Times of latency are generally higher for the first two age groups.

- *Variability* :
- Matrix D : The 5-6 y.o. are the most stereotyped and the general variability can as well be explained by the variability of incorrect sequences as by the variability of correct sequences. Looking at the number of reinforcements (NSD_2) that they receive, we may assume that their behavioral variability is less structured (adapted to the contingencies of D) than in older subjects. Adolescents and adults are the most variable. The 9-10 y.o. behave in the same way, though they have a superior U (IS). The global variability of these three age groups is due, for the largest part, to the variability of correct sequences.
- Matrix R : Global variability decreases in R among adolescents and adults (increase of % DS and decrease of U(S), U(CS), NSD_2, NCS). The 14-15 y.o. become the most stereotyped and adults keep a higher level of variability of incorrect sequences. The 5-6 y.o. and 9-10 y.o. stay at a higher level of variability (U(S)) than the older subjects (significant only for the 9-10 y.o.), even if their % DS also increase. The variability of incorrect sequences is particularly noticeable among the 9-10y.o. and it goes in the same sense as their bad performance in R.
- Matrix N : For the last two age groups, the better performance is parallell with an increase in the variability of correct sequences. The 5-6 y.o. become more stereotyped (similar level as in the third session in NNN) and the 9-10 y.o. keep a high level of global variability. The U(IS) of these 2 groups decrease while their performance improves, but it stays significantly higher than in the last two age groups.

- Experimental group RDN

Figure 1.5. (p.127) presents, for each index, mean values as a session, for each age group, in the group RDN.

- *Performance* :
- Matrix R : The 5-6 y.o. subjects do not seem to be influenced by the incoherence of visual cues in the first session (% CS). They behave in

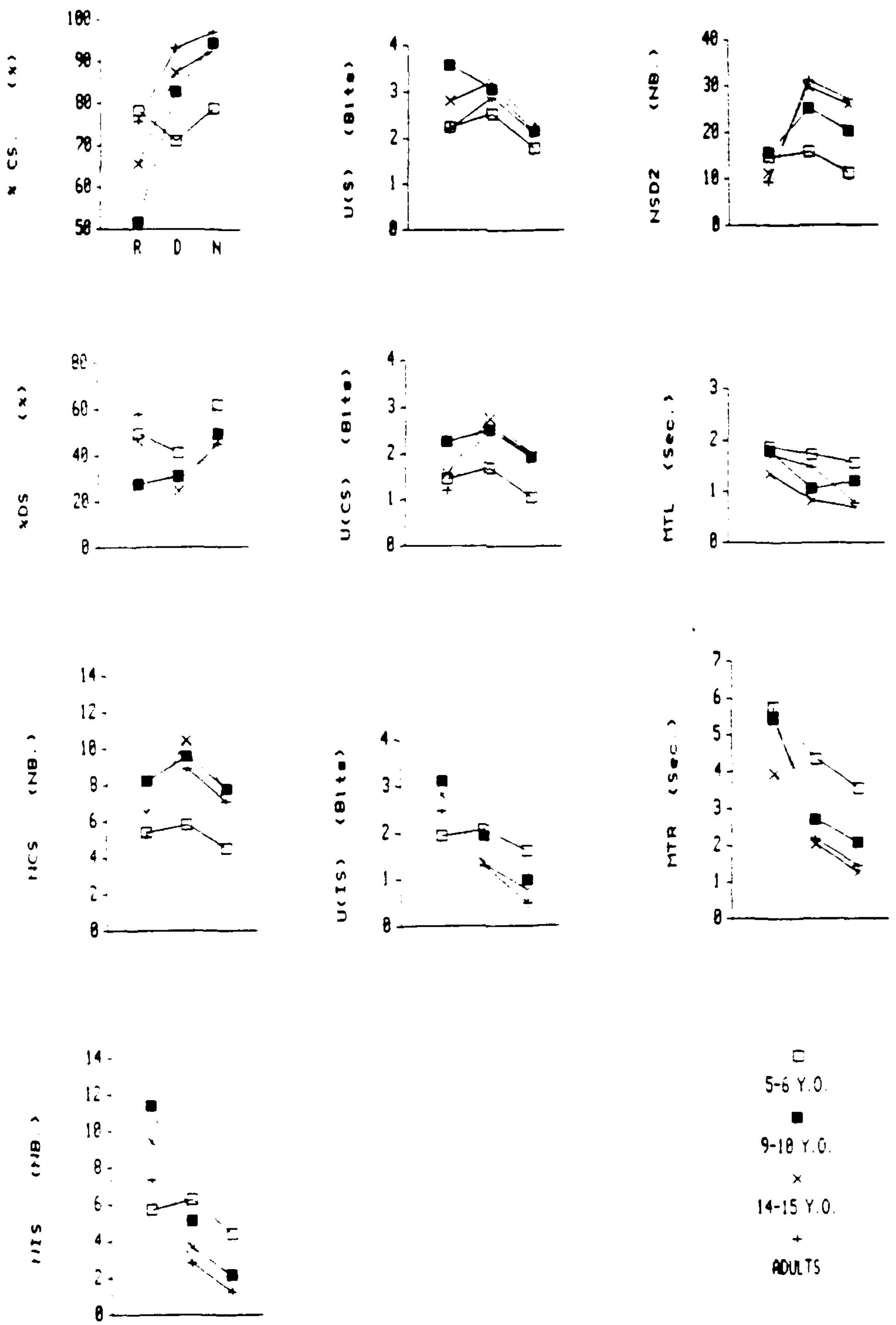

Fig. 1. 5. For each index, mean values as a function of session and for each age group, in the group RDN

the same way as with N or D in the first session, and they even obtain the highest % CS. The most disrupted are again the 9-10 y.o., with the lowest % CS The last two age groups also reach lower levels of performance, in comparison with the other experimental groups.

- Matrix D : The youngests keep a % CS similar to the one of the first session. Among other subjects, the % CS increases greatly (significantly superior to this of the 5-6 y.o.). Percentages of reinforcement (NSD_2) significantly rise in D except for the 5-6 y.o. The adaptation to the requirement of variability shows a tendency to increase with age. But this adaptation to matrix D does not seem as good here as in the other experimental groups including D.

- Matrix N : During the third session, the 5-6 y.o. stay at the same level of % CS as during the first session. The others reach higher levels of reinforcement (> 90% CS), like in NNN (significantly superior to this of the 5-6 y.o.). Times of realization and of latency decrease, for all age groups, from the first to the last session. The 5-6 y.o. are always the slowest (significant only for the sessions 2 and 3) and the 14-15 y.o. are the fastest. Adults get the same levels as those obtained by the 14-15 y.o. in the third session.

- *Variability* :
- Matrix R : For all subjects, the variability of incorrect sequences (NIS, U(IS)) is higher than the variability of correct sequences (NCS, U(CS)). The 9-10 y.o. are significantly the most variable, with regard to correct and incorrect sequences. The 5-6 y.o. and adults are the most stereotyped. Parallel to their good performance (the best of all the age groups), the youngests show the lowest variability of errors (significant for U(IS) and NIS).
- Matrix D : The variability of the 5-6 y.o. stays nearly stable, as well for dominant sequence as for incorrect sequences. They produce more often their dominant sequence and they are significantly more stereotyped than the other subject, with regard to their correct sequences. The 9-10 y.o. do not change their variability of correct sequences, but strongly reduce that of incorrect sequences. This last point can explain why they become globally less variable than in R. The sequences uncertainty of the last two age groups increase (significantly for adults). This increase is accounted for by the increase of the correct sequences variability, since the incorrect sequences variability significantly decreases among these two group.
- Matrix N : In each age group, global variability and, particularly, the variability of incorrect sequences is lower during the third session. The uncertainty of correct sequences is lower in N than in D, for all subjects, and it is a slightly lower than in R, for the first two age groups. It is higher than in R for adolescents and adults. The 5-6 y.o. are the most stereotyped with regard to their correct sequences and the most variable with regard to their errors (significant for the following cues : U(IS), NIS, U(CS)).

4.3.1.2. Comparison of the Naive subjects' Behaviors as a function of Matrix Type and of Age :

The results obtained with the matrixes N, R and D in first session were compared in order to study the spontaneous behaviors of naive subjects confronted with each type of matrix. In each age group, the results of subjects who had received N in the first session (subjects from experimental groups NNN, NRN and NDN) were put together in order to compare their results with those of subjects who had received R or D in first session (subjects from experimental groups RDN and DRN). The general profile of results with N will be refered to in first session as "global N" (GN).

For each index, means for each age-group and for each presentation order of matrix type can be found in Appendix 1, tables 1.12 to 1.21, pp 22-26.

Figure 1.6 (p 130) presents mean values of performance and variability indexes for each age group and each matrix type, in the first session.

For each index, Two-Way ANOVA (age X matrix type) in the first session (see Tables 1.43 and 1.44 in Appendix 1, pp 48-49) was completed: on one hand, by One-WayANOVA (age) and Newman-Keuls tests for each matrix type (in first session) (see Tables 1.53 to 1.62 in Appendix 1, pp 58-67) and on the other hand, by One-Way ANOVA (matrix type) and Newman-Keuls tests for 5-6 y.o. or Kruskal-Wallis (matrix type) (X^2) and Mann-Whitney tests (U) for 9-10 y.o., 14-15 y.o. and adults (see Tables 1.45 and 1.46 in Appendix 1, pp 50-51). These last 2 non-parametric tests ("X^2" and "U") were used when variances were not homogeneous and when sizes of compared group were too different.

Table 1.2 (p. 132) presents the DS distribution for each matrix type and for each age-group.

- Adults :

Results show that adults are very sensitive to environmental factors and to particular contingencies of reinforcement :

- their percentage of correct sequences is significantly lower in R than in N or in D. In the same way, variability of incorrect sequences (U(IS) and NIS) is higher with R than with the two other matrixes.This suggest that adults'behavior is disturbed by the incoherence (random displacement) of light cues.
- they are able to adopt more variable behaviors, when contingencies of reinforcement require it : the % DS is significantly lower in D and the variability of correct sequences (U (CS) and NCS) is significantly higher in D than in N or in R. They grasp the requirement of variability

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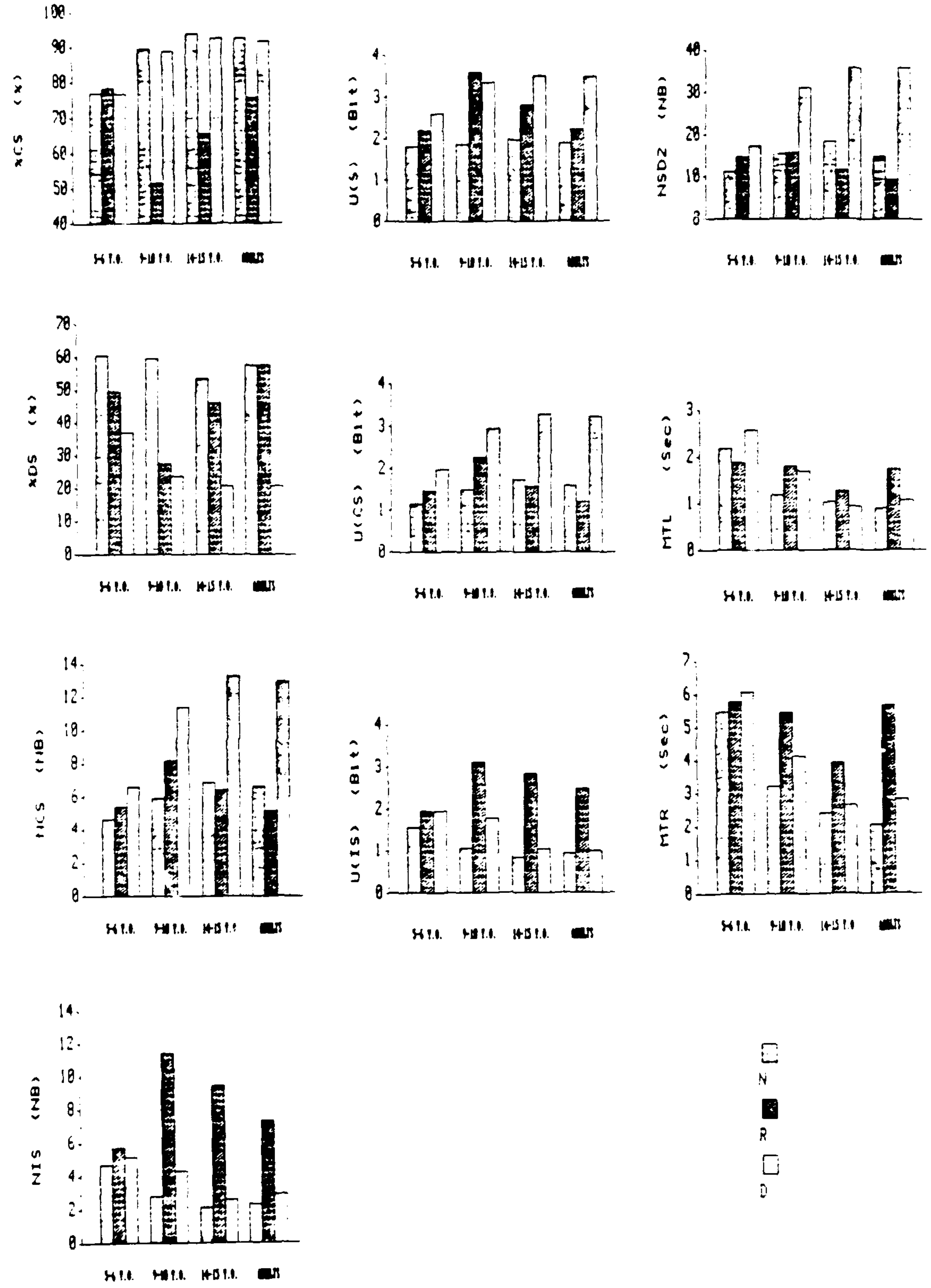

Fig. 1. 6. For each index, mean values as a function of age and of matrix type, in the first session

(NSD_2 is the highest in D) even if they do not receive as many reinforcements as in N or in R.

- it is the task in N that takes the lowest time (as well for MTR as for MTL). MTL are similar for R and D, but MTR is higher with R.
- dominant sequence types are differently distributed according to matrix type. The differences can be attributed to the effects of R : with this matrix, most subjects (73.7 %) prefer diagonal sequences as DS,while in N and in D, they prefer corner sequences (72.1 % and 60 % of the subjects, respectively). These results suggest that when no visual cues are made available to subjects, they adopt a "motor strategy", such as simple alternance of pushes on two buttons. When the visual cues are made available, adults prefer to use visual information, following the course of the moneybag on the matrix.

In D, adults have a slight tendency to choose more often other sequences as DS (20 % of the individuals) than in N (13.1 %). This is probably an effect of the variability requirement.

DOMINANT SEQUENCE TYPES

GN

DS \ AGE	5-6 y.o N = 49	9-10 y.o N = 57	14-15 y.o N = 56	ADULTS N = 61
1 CORNER	20 40.80	49 86.00	44 78.60	44 72.10
2 DIAGONAL	21 42.90	4 7	4 7.10	9 14.80
3 OTHER	4 8.20	3 5.30	8 14.30	8 13.10
4 INCORRECT	4 8.20	1 1.80	0	0

R

DS \ AGE	5-6 y.o N = 17	9-10 y.o N = 17	14-15 y.o N = 21	ADULTS N = 19
1 CORNER	0	0	1 4.80	1 5.30
2 DIAGONAL	17 100	11 64.70	16 76.20	14 73.70
3 OTHER	2	2 11.80	2 9.50	10.50
4 INCORRECT	4	2 23.50	2 9.50	10.50

D

DS \ AGE	5-6 y.o N = 49	9-10 y.o N = 57	14-15 y.o N = 56	ADULTS N = 61
1 CORNER	20 40.80	49 86.00	44 78.60	44 72.10
2 DIAGONAL	21 42.90	4 7	4 7.10	9 14.80
3 OTHER	4 8.20	3 5.30	8 14.30	8 13.10
4 INCORRECT	4 8.20	1 1.80	0	0

Table 1.2. : Absolute and relative frequencies of DS types as a function of age, for each matrix type in the first session.

- 14-15 y.o. subjects :

As a rule, adolescents behave in much the same way as adults. The number and the variability of incorrect sequences are higher in R, and the variability of correct sequences (U(CS), NCS and NSD_2) is higher in D (they obtain 71.7 % of reinforcements as the adults)

- though there is no significant difference between adults and adolescents, the latters' tend to be more disturbed by the incoherence of light cues (in R, they receive 65.6 % of reinforcements while the adults receive 75.7 % of reinforcements).
- MTR is higher with R than in D or N.
- as for adults, the DS distribution differ according to matrix type. In N and in R, we observe the same DS distributions as for adults. However, in D, 61.9 % of the adolescents (against 20 % of the adults) prefer to produce other sequences than corner or diagonal sequences.

- 9-10 y.o. subjects :
- As for the older subjects, the number and the variability of incorrect sequences are significantly higher in R and the variability of correct sequences is higher in D. Moreover, the variability of incorrect sequences is significantly more important in D than in N and the variability of correct sequences is significantly more important in R than in N. This can explain why there is no difference between R and D with regard to global variability. These effects can be explained by the subjects' difficulty to adapt themselves to the particular constraints of these matrices : in D, they emit more erroneous sequences and they are less variable than older subjects (62 % of reinforcement against 71.7 %v for the adults and adolescents) and they are much more disturbed by the random displacement of light cues (in R, 51.5 % of reinforcement against 75.7 % for adults and 65.6 % for adolescents).
- MTR and MTL are lower in N than in R or D. In D, these subjects are significantly slower than older and they also complete the sequences more slowly than older subjects in N. No difference between age groups in R is noted as this matrix takes more time to be solved by all subjects.
- in N and D, the DS distribution is approximately the same as for older subjects (no significant difference). However, parallel to their bad performance in R, there is a higher percentage of subjects who emit erroneous sequences as DS (23.5 %) than among adults or adolescents (9.5 %) .

- 5-6 y.o. subjects :
- the 5-6 y.o. are not very disturbed by the incoherence of the visual cues in R. The % CS is similar in N (77.08 %) and in R (78.3 %). They are the best performers with the matrix R and they tend to be the most stereotyped. This lower behavioral variability in R can account for their better performance.
- the 5-6 y.o. have the greatest difficulties to adopt more variable behaviors when contingencies require it : their percentages of correct sequences (76.9%) and of reinforcements (34.46 %) are significantly lower than those of other subjects (even if they show themselves more

variable in D than in N).

- in N, they also tend to be more stereotyped than other subjects (however,difference between age-group is not significant). In fact, these young children adopt quite constant behaviors, independently of the particular conditions to which they are submitted.
- MTR and MTL are similar for the three matrices and the subjects are always slower than the other ones.
- except in R, where the majority of subjects of all age groups emit diagonal sequences as DS, the 5-6 y.o. also differ from other subjects with regard to their choice of DS in N and D : they always emit more diagonal DS. This observation concords with the remark made above about the constancy of their behaviors in all situations. The motor strategy that these children adopt most often allows them to by pass difficulties, even though they do not master the functioning rules of each matrix type... However, in some case - as in D - it does not help them because of the few possibilities for reinforcement it offers.

4.3.1.3. Effects of Pre-training on Behavioral Variability

- The term "pre-training" is used here, not to designate the preliminary phasis of training proper. It refers to the initial session or to the previous sessions to which subjects have been exposed. For example, "pre-training in N" means that a session in a given condition (N, R or D) is considered as a function of the N condition prevailing in the previous session(s).
- Let it be reminded that, for each index, means as a function of age and of presentation order of matrix types can be found in Appendix 1, Tables 1.12 to 1.21, pp 22-26.

- Effect of pre-training in N on behavior in N, D and R :

Results obtained with the matrices N, D and R, by the pre-trained subjects in N, were compared. In each age group, the second sessions of the experimental groups N<u>N</u>N, N<u>R</u>N and N<u>D</u>N were taken into account.

Figure 1.7 (p. 135) presents the mean values of performance and variability indices according to age and to matrix types, in the second session (after pre training in N).

For each index, Two-Way ANOVA (<u>age X matrix type</u>) in the second session (see Tables 1.43 and 1.44 in Appendix 1, pp 48-49) was completed : on the one hand, by One Way ANOVA (<u>age</u>) and Newman-Keuls tests for each matrix type in second session (see Tables 1.53 to 1.62, in Appendix 1, pp 58-67) and, on the other hand, by One Way ANOVA (<u>matrix type</u>) and Newman-Keuls tests for each group, in the second session (see Tables 1.47 and 1.48 in Appendix 1, pp 52-53).

For adults and adolescents, differences observed between matrices N, R and D in second session are similar to those observed in the first session.

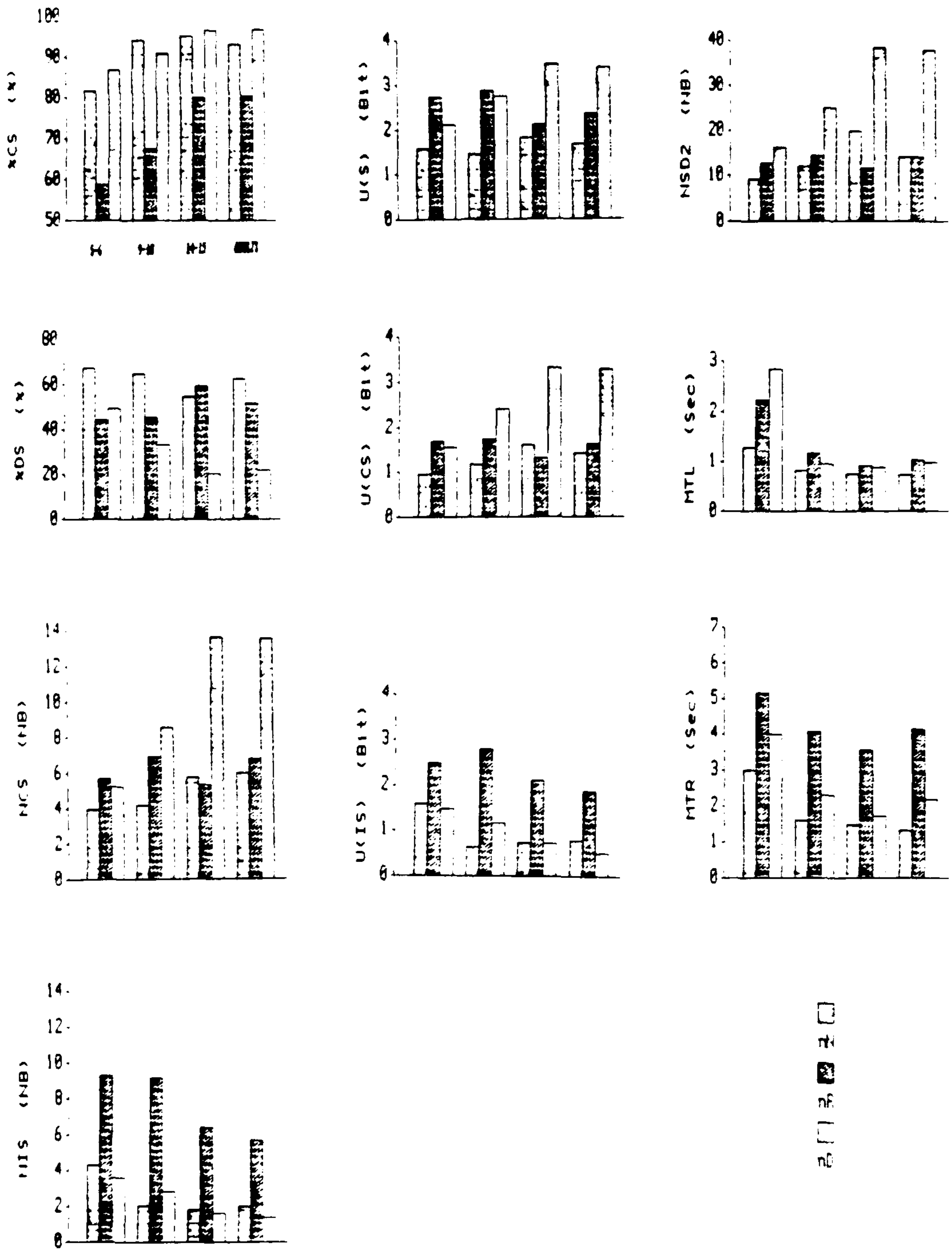

Fig. 1. 7. For each index, mean values as a function of age and of matrix type, in the second session, with the first session being N in all cases (lower case letters are used as symbols for first session condition, capital letters for second session condition)

The behaviors of subjects pretrained in N are not significantly different from those of naive ones.

The significant differences observed for naive 9-10 y.o. subjects between matrices N and R with regard to variability of correct sequences (higher in R than in N) and between matrices N and D with regard to variability of incorrect sequences (higher in D than in N), diminish and are not significant for pretrained subjects.

While for the naive 5-6 y.o. subjects, no significant difference was found between matrices N and R and between matrices R and D, for the pretrained subjects, the % CS is significantly lower in R than in N or in D, and the variability of incorrect sequences is significantly higher in R than in N or in D.

For each matrix type and for each age group, comparison between pretrained subjects (Figure 1.7, p. 135) and naive subjects (Figure 1.6., p. 130) enables to note the following tendencies (for example, in each age group, the second session of the group N<u>R</u>N is compared to the first session of the group <u>R</u>DN) :

For adults and adolescents, pre-training slightly increases the performance and the stereotypy in N. It does not modify these subjects' capacity to be more variable when contingencies require it and it tends even to facilitate the performance of adolescents in R (they receive 14.5 % more *reinforcements* than naive subjects).

A similar facilitation effect of pre-training in N on the performance in R, is found with the 9-10 y.o. (pretrained subjects obtain 16.05 % more reinforcements than naive ones). In parallel, the stereotypy is slightly higher in N and in R for pretrained subjects. However, for the 9-10 y.o. subjects, habituation to the task interfer with the capacity to adapt to the variability requirement in D (pretrained subjects obtain 12.12% of reinforcements less than naive ones, even though their % CS is 2.15 % higher than in naive subjects).

These pre-training effects influence the way in which the 9-10 y.o. differentiate themselves from other age groups subjects.

While in the first session, the 9-10 y.o. performance was significantly *inferior and while they were more* variable in R as compared to other subjects, they do not behave differently from others with R in the second session. The reverse phenomenon is observed with the matrix D.

Contrary to older subjects, pretraining in N has a disturbing effect on the youngest children behavior in R. The performance of pretrained subjects is inferior to that of naive ones (% CS : -19.7 %) and they are also more variable. Thus, in second session, 5-6 y.o. subjects become significantly less good performers than other subjects, while being the best performers and the most stereotyped in R when it is the first session.

As for the 9-10 y.o., the pretraining reduces their variability in D. However, it must be noted that this lower variability in pretrained subjects is mainly due to the elimination of incorrect sequences. This indicates that the lower variability of the younger subjects compared to the older may be explained by a difficulty to master the task and its constraint.

- Effect of pre-training in D (versus N) or R (versus N) on subsequent behavior in R or D :

In each age group, the second sessions of the experimental groups NRN and DRN (NDN and RDN) were taken into account. Figure 1.8 (p. 138) presents mean values of each index in R and D (second session) as a function of age and of pretraining type.

No matter which age group is considered, the type of pretraining (with D (versus N)or with R (versus N)) has no significant effect on the behaviors observed in R or in D in the second session. However, we can note the following tendencies :

Concerning the behaviors in R :

- For adults and adolescents, the pre-training with the matrix D seems to have a stronger facilitation effect than with N, on the performance in R. It also leads to a higher stereotypy in R. Such an effect seems likely to be related to the good performance in R (as we have seen in the other analysis including R). *It seems unlikely that such an effect* can be attributed to the matrix D itself. So, pre-training in D would help the subjects in finding more easily a satisfying solution in R.
- For the 9-10 y.o., the facilitation effect of the pre-training in D is less marked than the one of the pre-training in N. Like naive subjects of this age group, the 9-10 y.o. pre-trained with D, are less good performers and most variable in R than others subjects, while there is no difference between the 9-10 y.o. pre-trained with N and other subjects. It seems that the request of variability during the first session, does not help the 9-10 y.o. to find a good solution in R.
- For the 5-6 y.o., the disturbing effect of pre-training in D is less important than the one obtained with pre-training in N. Subjects with D in the first session behave in a similar manner as naïve subjects in R. This is probably due to the fact that when matrices are more different from each other (it is the case between D and R), the youngest subjects' behaviors are less influenced by their previous behavior.

Concerning the behaviors in D :

- Compared with the pre-training in N, the pre-training in R leads to a slightly lower variability in D, for adults and adolescents (but the differences betweeen naive and pre-trained subjects are very small).
- For the 9-10 y.o., the number and the variability of incorrect sequences in D are higher after the pre-training with R than after N, but the two types of pre-training effects are not different with regard

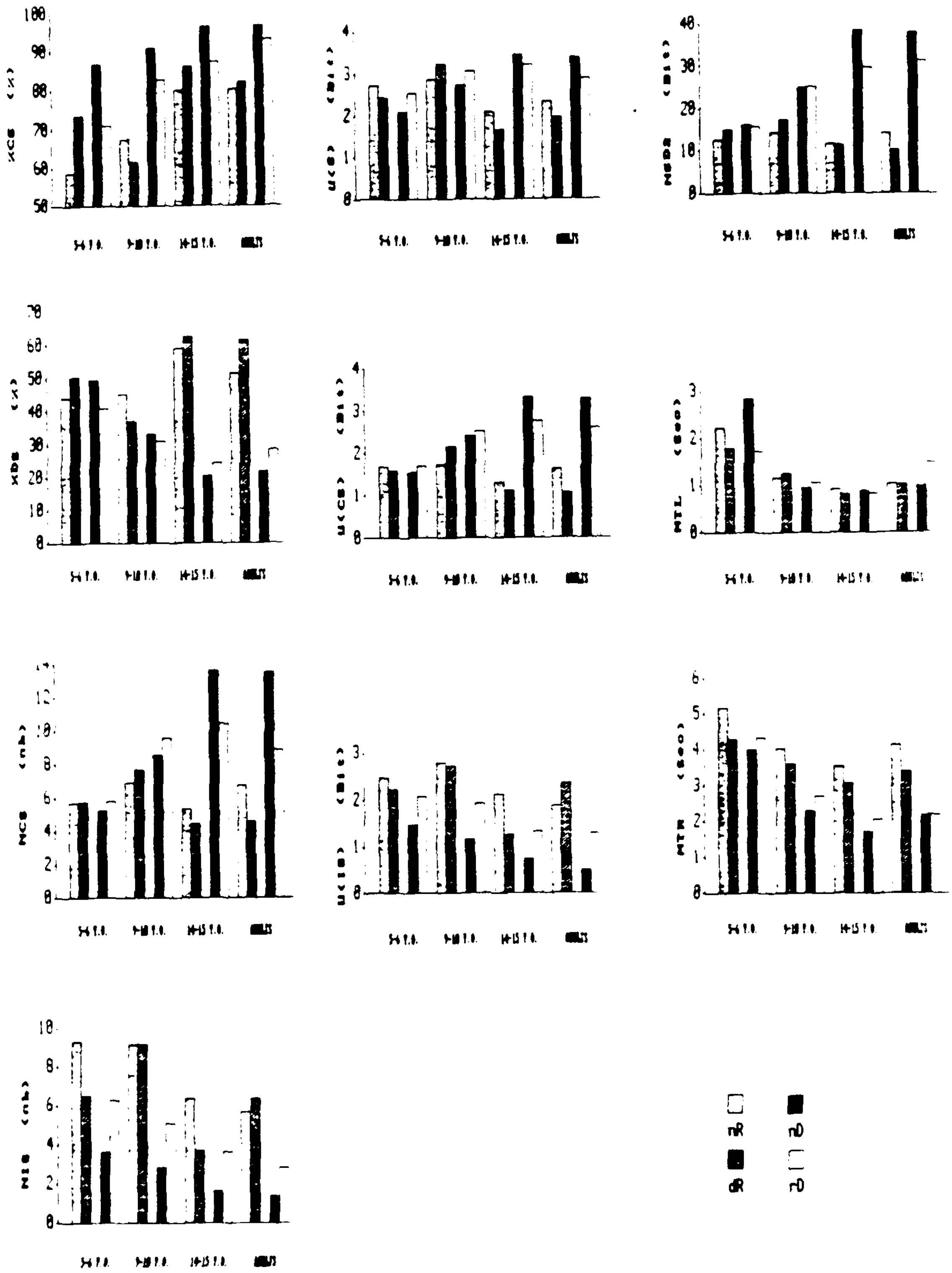

Fig. 1. 8. For each index, mean values in R and D (second session) as a function of age and of pre-training type (lower case letters are used as symbols for first session condition, capital letters for second session condition)

to the variability of correct sequences (U(CS) and to the performance (NSD_2) in D.

- The same phenomenon is observed among the 5-6 y.o.
- For these last two age groups, the higher number of incorrect sequences after R, as compared to the number after N, probably reflects their additional trials and errors to establish the new relations between their pushes and the displacements of the bag.

- Effects of five different pre-trainings on the behaviors in N :
In each age group, the last sessions (N) of the five experimental groups were compared.

Figure 1.9 (p. 140) presents mean values of each index in N (third session) as a function of age and of pre-training type.

For each index, Two-Way ANOVA (age X pre-training) in the third session (see Tables 1.49 and 1.50 in Appendix 1, pp 54-55) was completed: on one hand by one-way ANOVA (age) and Newman-Keuls tests in the third session of each experimental group (see Tables 1.53 to 1.62 in Appendix 1, pp 58-67) and, in the other hand, by One-Way ANOVA (pretraining) and Newman-Keuls tests for each age group, in the hird session (see Tables 1.51 and 1.52 in Appendix 1, pp 56-57). These statistical analysis concern only in the last sessions (N) of the 5 experimental groups.

The statistical analysis does not reveal any significant effect of the type of pre-training (NN, NR, ND, DR, RD) with regard to the performance and to the variability of incorrect sequences, during the last session. Only the effect of age is significant : in all the experimental groups, the 5-6 y.o. have the lowest performance.

Generally, the first hundred trials mainly influence the correct sequences variability.
- Adults, adolescents and 9-10 y.o. who have been submitted to the matrix D during pre-training, show more variable behavior in N in the last session. At least two hypothesis can be suggested : first, some subjects having understood that several correct sequences can be used, may vary during the last session so as to interrupt the task monotony (but if it were the case, subjects in the group NNN; would be expected to have adopted the same behavior in the third session); secondly, it is quite possible that the higher variability appears in the beginning of the last session only, before the subjects notice the modification of contingencies i.e. to return to N condition. The pre-training which leads to the most variable behaviors in N is ND, followed by RD, for adults and adolescents. For the 9-10 y.o., it is DR followed by RD. The

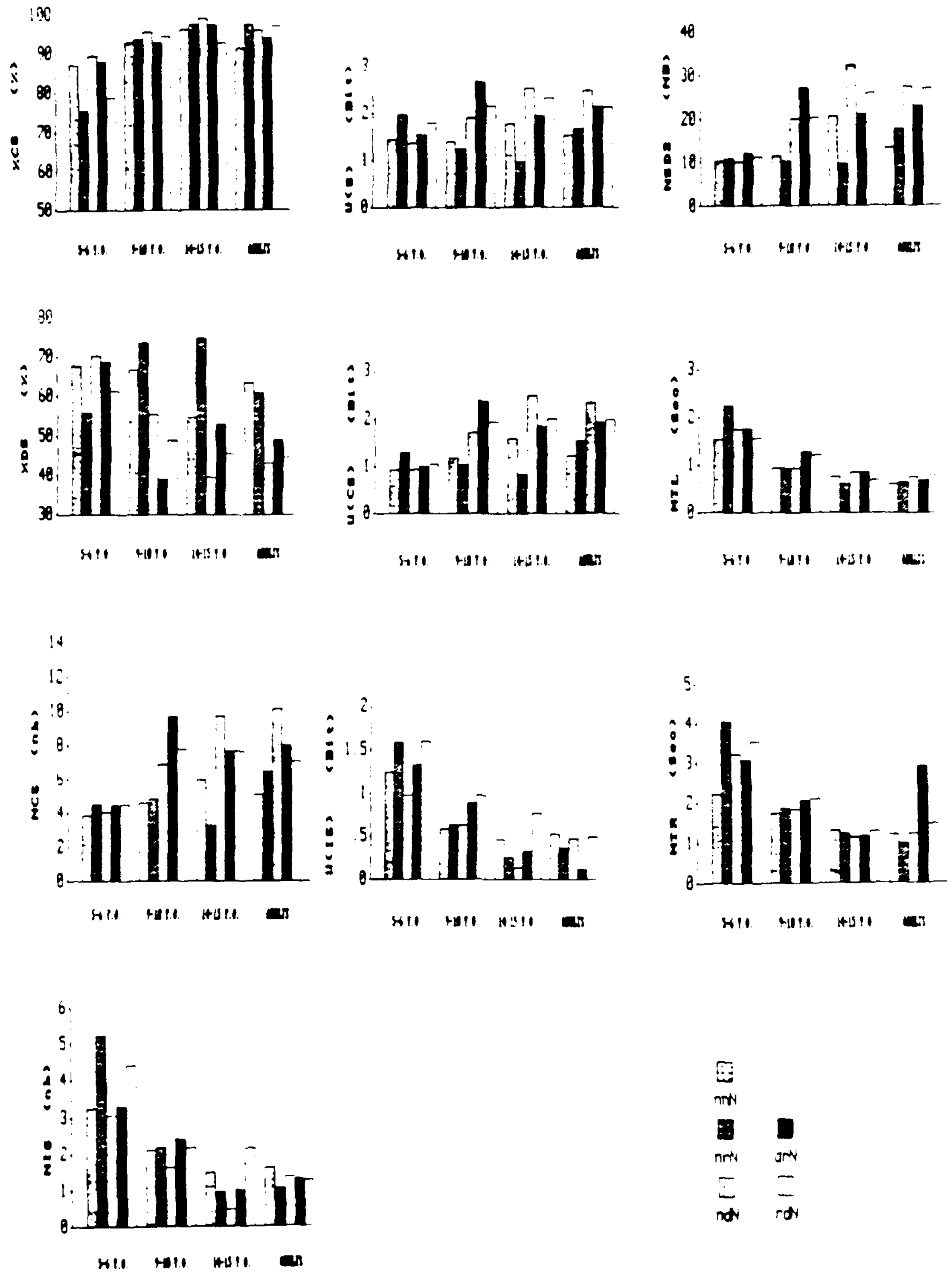

Fig. 1. 9. For each index, mean values in N (third session), as a function of age and of pre-training type (lower-case letters are used as symbols for first and second sessions conditions, capital letters for third session condition)

pre-trainings which lead to the most stereotyped behaviors during the last session are NN and NR.

- For the 5-6 y.o., the behaviors in N are not modified by a particular type of pre-training. They are the most stereotyped in all the experimental groups. Except the last session of the experimental group DRN, in which the 9-10 y.o. are the most variable, adults and adolescents are the most variable during the last sessions. However, no significant differences between age groups for the experimental groups NNN and NRN are noted.

4.3.1.4. Intra-sequence organization : Conditional Uncertainty of each response, as a function of age and of matrix type :

In order to estimate the organization of behavior of subjects of each age group when they are faced with each matrix type, an other index has been computed : the Conditional Uncertainty of each reponse within the sequence (U (R/s)). This "intra-sequence" analysis enables to estimate the way the subjects regulate each of their responses as a function of the previous responses, in order to produce correct sequences (6 responses with 3 responses on each response button).

The conditional uncertainty of one response x is an estimate of the possibility to predict x, according to the x-1 responses (pre-sequence s) already produced within a sequence :

$$U(R_i/s) = -\sum_{i=1}^{2}\sum_{j=1}^{k} pi\ p(R_i/sj)\ \log_2 p(R_i/sj),$$

with :
- pi = the probability of the response i (R_i)
- p (R_i/sj) = the conditional probability of R_i, according to the pre-sequence sj
- k = the number of possible different pre-sequences i-1

For the first response, simple uncertainty U(R1), (not Conditional Uncertainty) is computed because, in this case, there is no pre-sequence.

The U(R1) and U(R/s) which are presented in Appendix 1 (Table 1.22 p 27), are means computed on the set of subjects' results for each age and each matrix type, in the first session.

Responses of correct and incorrect sequences are taken into account.

During the first session, for each matrix type (GN, R and D) and for each age group, a decrease of the conditional uncertainty of the

each age group, a decrease of the conditional uncertainty of the responses U(R/s), from the first to the sixth response is observed (see Figure 1.10, p. 142).

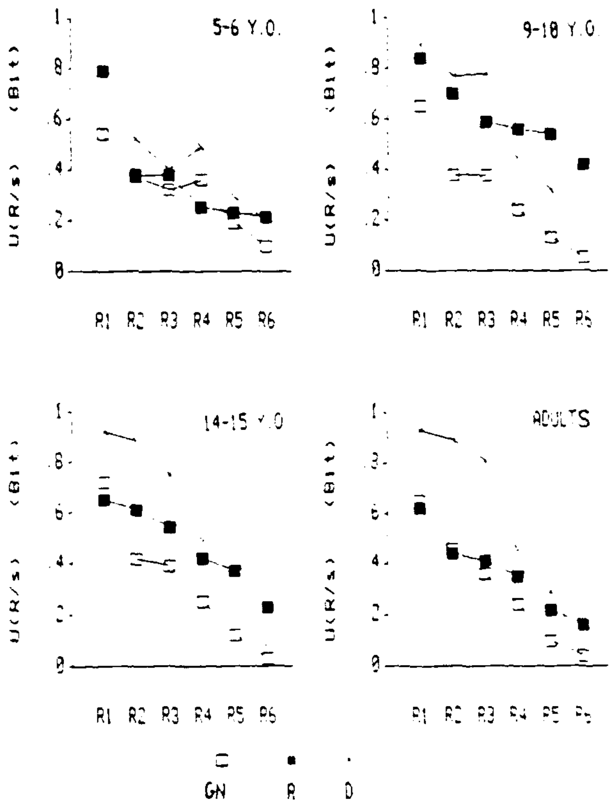

Fig.1.10. Mean values of U(R1) and U(R/S) as a function of age and of matrix type, in the first session

It seems possible to distribute the six responses into two "units". Within the first "unit", grouping the first three responses, subjects can push on any of the 2 response-buttons without taking into account the previous responses. On and after the fourth response, subjects have to take into account their previous responses to be sure of success. These last three responses constitute the second "unit". The first "unit" can be considered as the element of variation of the sequence; the second unit, can be viewed as the element of regulation of the sequence (to complete a correct sequence). $U(R_6/s)$ is never equal to zero, because there are

always, at least, some incorrect sequences.

The form of the curves and the differences between age groups vary as a function of matrix type. Globally, U (R/s) analysis confirms the features already described.

For the matrix N and for the age groups, U(R1) is never maximum and U(R/s) decreases rapidly, to tend to zero with the last response. U(R/s) is always highest in 5-6 y.o. for the last three responses (elements of regulation), parallel to their highest level of incorrect sequences.

U(R1), U(R_2/s) and U(R_3/s) are similar in N and in R for adults, but these subjects keep more variable behaviors in R for the last three responses (more incorrect responses.) The reverse phenomenon is U(R1) is near the maximum and U(R/s) decreases more slowly with regards to the first 3 responses. Then it decreases more rapidly to reach the same U(R_5/s) as in R and the same U(R_6/s) as in N. The distinction between the two sequence units appears, thus, very clearly : subjects especially vary at the beginning of the sequence, but are able to adjust their responses in the second sequence unit to produce correct sequences.

Adolescents' behavior is not fundamentally different from the adults' one (they are just a little more variable in R).

The 9-10 y.o. are, on the contrary, as variable in R as in D up to R_4. They keep high levels of U(R/s) for the last two responses, showing their incapacity to adjust their behaviors under these contingencies. Their U(R1) and U(R/s) are always higher than those of other subjects (confirming our previous analyses).

After their first push, the 5-6 y.o. quickly become more stereotyped than other subjects in R and in D. This goes in the same sense as their great % DS in R (diagonal sequences). In D, like in N, their U (R_6/s) stay higher than in other age groups.

U (R/s) for the second and the third sessions are not presented, because the results do not significantly differ from those already described.

4.3.1.5. Performance and variability as a function of sex of subjects.

For each index, means as a function of age and of sex, in the first session of the experimental groups NNN, RDN and DRN can be found in Appendix 1, Tables 1.12 to 1.21, pp 22-26.

In each age group, for each index, Two-Way ANOVA (sex x matrix type) were used in first and second session and Two-Way ANOVA (sex x pre-training) were used in third session.

An effect of sex is observed in the first session only and for 9-10 y.o. and adults only.

- Among the 9-10 y.o., the effect of sex is significant for the % CS ($F(1,90)=4.544$, $p=.036$), for NIS ($F(1,90)=4.935$, $p=.029$) and the number and the variability of incorrect sequences are higher for boys than for girls. The 9-10 y.o. boys are thus less able performers than girls and they are more variable in their errors.
- The same phenomenon can be observed among adults, for NIS ($F(1,99)=4.22$, $p=.04$) and for U(IS) ($F(1,99)=5.94$, $p=.02$) Moreover, NCS is here lower for females than for males ($F(1,99) = 5.387$, $p = .02$) in N and in R (this is particularly marked in N). This last difference is not found in D. Females show, thus, a tendency to be more stereotyped than males, except when reinforcement contingencies require variability.
- There is no significant difference related with sex with regard to DS distributions.

4.3.1.6. Performance and variability of adults, as a function of school training.

For each index, One-Way ANOVA (School training) were used in GN (grouping the first sessions of experimental groups NNN, NRN and NDN).

No relation can be established between study type ("humanities, "neutral", "scientific") on one hand and performance and variability in N on the other hand .(a detailed list of study types can be found in Appendix 1, Table 1.1, p 11).

4.3.2. COGNITIVE TASKS

4.3.2.1. Description of results for each cognitive tasks in each age group

- Adult subjects (n=100)
- *Non-perceptual serial classification* :

The mean number of successful items, on the 6 ones proposed, is 4.73 ($\sigma = 1.27$). 61% of adults correctly complete 5 or 6 items and 37% complete the totality of items (see Table 1.3)

These results are similar to those obtained by Botson and Deliège (1976).

There is no difference due to sex or to type of study.

Age groups / number of correct items	Adults (n = 100)	14-15 y.o. (n = 98)
o - 2	6 6.00	11 11.20
3 - 4	33 33.00	33 33.70
5 - 6	61 61.00	54 55.10

Table 1.3 Adults and 14-15 y.o. : absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of correct items at the non- perceptual serial classifications task).

- *Permutations* :

  70 % of adults adopt a systematic procedure to produce the totality of permutations (with 3, 4 and 5 elements), are able to understand the calculation principle and to apply it to any number of elements (see Table 1.4.).

  There is no difference due to sex or to type of matrix.

Age groups / categories	Adults (n = 100)	14-15 y.o. (n = 98)
1	7 7.00	28 28.60
2	7 7.00	12 12.20
3	16 16.00	26 26.50
4	70 70.00	32 32.70

Table 1.4 Adults and 14-15 y.o. : absolute and relative frequencies of subjects in each of 4 categories of performance in the permutation task (cat. 1 = lowest performance).

- *Group Embedded Figures Test (GEFT)* :

With regard to the field dependence or independence (cognitive style), the mean correct item on the 18 items proposed at the GEFT is 13.95 ($\sigma = 3.89$). This mean is approximatively the same as the mean (14) obtained by the sample of subjects, that was used to standardize the French version of the test. One third of adults can be considered as very field- dependent (see Table 1.5).

Age groups / number of correct items	Adults (n = 100)	14-15 y.o. (n = 98)
o - 12	30 30.00	58 59.10
13 - 16	37 37.00	31 31.60
17 - 18	33 33.00	9 9.20

Table 1.5 Adults and 14-15 y.o. : absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of correct items at the GEFT).

As has already been observed in the other studies concerning this cognitive style, women are significantly more field dependent than men : 23.1 % of women succeed in 17 or 18 items, as compare to 39.3 % of men ($X^2 = 6.0758$, df = 2, p = .0479).

The type of study is also significantly related to cognitive style : 46.7% of "Scientific" subjects succeed in 17 or 18 items, as compare to 22.2% of "neutral" subjects and 21.1 % of "humanities" subjects. ($X^2 = 12.347$, df = 4, p = .0149)

- 14-15 y.o. subjects (n=98) :

- *Classification tasks (Level II)* :

It is reminded that :

- Level I : classification task includes 8 elements, which can be dichotomized according to 3 criteria.

- Level II : classification task includes 16 elements, which can be dichotomized according to 6 criteria.

Only 27.6 % of adolescents spontaneously produce a multiplicative classification .

In the second part of the task (imposed successive dichotomies), they produce, on average, 5.74 correct dichotomies (σ =.56).

In the third part (imposed successive multiplicative classifications) they produce 6.66 correct multiplicative classifications (σ =3.22). 80.6% of these subjects produce the totality of the 6 possible dichotomies and 12.2% produce between 11 and 15 multiplicative classifications (see Table 1.6).

While 56.1 % of the subjects adopt a systematic procedure to produce their multiplicative classifications (they choose one dichotomy criterion that they cross with the other ones and they do the same with a second, then with a third ... dichotomy criterion), 25.5 % of the subjects seem to produce their different classification at random.

Age groups / number of correct classifications	14-15 y.o. (n = 98)	9-10 y.o. (n = 91)
0 - 5	39 39.80	74 81.30
6 - 10	47 48.00	15 16.50
11 - 15	12 12.20	2 2.20

Table 1.6 14-15 y.o. and 9-10 y.o. : absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of correct multiplicative classifications (level II)).

- *non-perceptual serial classification* :

The mean number of successfull items, on the 6 proposed, is 4.37 (σ = 1.46). 27% of adolescents correctly complete the totality of items, to 37% of adults. However, subjects' distributions do not differ significantly (see Table 1.3, p. 145).

- *permutations* :

Adolescents are not as good performers as adults : only 32.7% of subjects (compared to 70% of adults) know the permutations calculation principle and are able to produce systematically the totality of permutations. Adults' distribution and adolescents' distribution are significantly different (X^2 = 30.4365, df = 3, p = .000), (see Table 1.4, p. 145).

The difference between adults and adolescents can be attributed, in part, to a sample effect : one part of the adolescents will follow studies at University. So, probably, other factors than age could explain the difference of performance.

- *GEFT* :

The mean number of correct items at the GEFT is 10.85 ($\sigma = 4.70$). Adolescents are significantly more field dependent than adults (see Table 1.5, p. 146) ($X^2=24.08$, df=3,p=.000).

There is no difference linked with sex, in the four cognitive tasks.

- 9-10 y.o. subjects. (n = 91).

- *Multiplicative seriation task* :

A great majority of subjects can arrange the elements according to the two dimensions, but only successively. (see Table 1.7).

Age groups / categories	9-10 y.o (n = 91)
1	8 8.80
2	62 68.10
3	21 23.10

Table 1.7 9-10 y.o. : absolute and relative frequencies of subjects in each of 3 categories of performance in the multiplicative seriation task (cat. 1 = lowest performance).

- *Classification tasks (Levels I and II)* :

18.7% of the 9-10y.o. subjects spontaneously produce a multiplicative classification in the Level I task, compared to 16.5% in the Level II task (27.6% among the adolescents). Differences between the 9-10 y.o. and the 14-15 y.o. for the Level II task are not significant.

The subjects produce on average, 2.5 dichotomies ($\sigma = .70$), (maxima : 3) and 1.98 multiplicative classifications ($\sigma = 1.04$), (maxima : 3) in the Level I task. 61.5% of subjects produce the totality of the three possible dichotomies and 39%, the totality of the three possible

multiplicative classifications (compared to 69% of the 8-9 y.o. subjects observed by Piaget and Inhelder (1967, p. 211)).

In the Level II task, they produce an average of 5.26 dichotomies (σ = 1.00), (maxima : 6) and 3.65 multiplicative classifications (σ = 2.66), (maxima : 15) compared to 5.74 and 6.66 among the 14-15 y.o., respectively. 56% of subjects produce the totality of the 6 possible dichotomies and 2.2%, between 11 and 15 multiplicative classifications (compared to respectively, 80.6% and 12.2% among the 14-15 y.o.), (see Table 1.6, p. 147). Differences between the 9-10 y.o. and adolescents are here significant (X^2 =12.1447, df = 1, p= .0005, for the dichotomies number; X^2 = 34.287, df = 2, p = .000, for the multiplicative classifications number).

Girls produce a significantly higher number of Level II multiplicative classifications than boys : 68.9% of the girls produce from 0 to 5 correct multiplicative classifications and 28.9% execute from 6 to 10, compared to 93.5% and 4.3% , respectively, for the boys (X^2 = 10.0028, df = 2, p = .0067).

- *Perceptual serial classification* :
The mean of successfull items on the 3 ones proposed, is 2.04 (σ =.94). 40.7% of subjects succeed in the totality of items (see Table 1.8.). In Botson and Delièges's results (1976), 30% of the 9 y.o. subjects and 60% of the 10 y.o. subjects succeeded in the 3 items.

number of correct items \ Age groups	9-10 y.o. (n = 91)	5-6 y.o. (n = 67)
0 - 1	28 30.80	41 61.20
2	26 28.60	19 28.40
3	37 40.70	7 10.40

Table 1.8 9-10 y.o. and 5-6 y.o. : absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of correct items at the perceptual serial classifications task).

- *Inclusion task* :
  All subjects, except one, correctly solve the inclusion problem.

- 5-6 y.o. subjects (n = 67).

- *Simple seriation task* :
  44.3% of subjects produce a correct seriation (with or without the direct insertion of the remaining element).

- *Classification task (Level I)* :
  In the first part of the task (spontaneous classification), 17.8% of the 5-6 y.o. subjects do not produce a real classification, while 82.2% of them succeed. Only 3.9% of the latter subjects produce a multiplicative classification. They make an average of 1.25 dichotomies ($\sigma = .77$) and .29 multiplicative classifications ($\sigma = .558$) (compared to 2.50 and 1.98, respectively, for the 9-10 y.o.).

  Only 6% of them produce the totality of the 3 possible dichotomies and 1.5%, for the totality of the 3 possible multiplicative classifications (compared to 61.5% and 42.9%, respectively, for the 9-10 y.o.). Differences between the two age groups concerned are found to be significant ($X^2 = 50.5883$, df = 1, p = .000, for the dichotomies number; $X^2 = 34.921$, df = 1, p = .000 for the multiplicative classifications number).

  64.6% of the youngest subjects make 0 or 1 dichotomy only and 74.7% do not produce any correct multiplicative classification.

- *Perceptual serial classification* :
  The mean number of successful items, on the 3 ones proposed, is 1.0 ($\sigma = 1.01$) (2.04 for the 9-10 y.o.). Only 10.4% of subjects succeed in the totality of items (compared to 40.7% of the 9-10 y.o.) (see Table 1.8, p. 149). The youngest subjects performance is thus significantly different from that of the 9-10 y.o. ($X2 = 20.827$, df = 2, p = .000).

- *Inclusion task* :
  Only one subject solves the inclusion problem.

  There is no difference related to sex, in the four cognitive tasks.

4.3.2.2. Relations between cognitive tasks :

In each age group, results of each cognitive task were put in relation with the results of each other. Statistical analysis (correlations) were used only when results could be considered as measurable variables (which was not the case for permutations task, spontaneous classifications or seriation tasks).

- For adults, no relation has been found between the results of each cognitive task.
- For, adolescents, the performance at the non-perceptive serial classification task is positively correlated with the number of correct dichotomies ($\rho = .3930$, $p < .001$) and with the performance at the GEFT ($\rho = .3003$, $p < .01$).
- For the 9-10 y.o., the number of level 1 correct dichotomies is positively correlated with the number of correct multiplicative classifications, produced on the same elements ($\rho = .3081$, $p < .01$) and the performance at this task is itself positively correlated with the number of Level II correct multiplicative classifications ($\rho = .5595$, $p < .001$).
- For the 5-6 y.o., as for the 9-10 y.o., the number of dichotomies is correlated with the number of multiplicative classifications ($\rho = .3013$, $p < .01$). For these subjects, the number of dichotomies is equally correlated with the performance at the perceptive serial classification task ($\rho = .5059$, $p < .001$).

4.3.2.3. Relations between cognitive task results and performance and variability indices in N in first session. :

Only the results of subjects who had been submitted to the matrix N in the first session were taken into account (61 adults, 57 adolescents, 57 "9-10" y.o. and 49 "5-6" y.o.).

The results of subjects who had received R or D in first session were not taken into account, because of the limited number of subjects in some groups (for example, among the adults, there are only 4 subjects with D in the first session, who succeed 3 or 4 serial classification items (second category)).

In each age group, One Way Anova and Newman-Keuls procedure were used for each performance and variability indices (in GN), as a function of performance in each cognitive task (groups have been made from categories used in the treatments of data). Correlations were also used when tasks results could be considered as measurable.

Whatever the age group, the statistical analysis reveal no relation, between the subjects' performance cognitive tasks and their performance or variability in N in first session.

4.4. CONCLUSIONS OF EXPERIMENT 1

To conclude, it is appropriate to review the main results of Experiment 1 with the questions it was addressed to in mind :

1. Does contingent reinforcements produce stereotypy, even when this last one is not required ?
2. What is the role of the information given by the environment ? What is the role of visual cues ? Do they influence the sequence form ?
3. Is it possible to induce behavioral variability ?
4. Which role is played by the individuals' experimental history, depending upon the situations they have been experiencing ?
5. Are there relations between subjects' cognitive capacities, their cognitive style (field dependence/independence) and their performance and variability at the Visual Matrix task ?

The major results can be stated as follows :

1. In the normal situation (N), results indicate that the mastery of the task is increased as age increases and they confirm the observations made in previous similar works with College students or with children, concerning the establishment of a stereotyped behavior as a function of the number of trials (Boulanger, 1983; El Ahmadi, 1982; Schwartz, 1982c; Wong & Peacok, 1986). It is important to note that, even in the third session, stereotypy never becomes complete. Individuals of all age groups always make several different correct sequences.
   If the overall spontaneous variability is approximatively the same for all age groups, its components are evolving with age : the youngest subjects produce the same number of different correct or incorrect sequences but the number and the variability of different corect sequences increase with age while these of incorrect sequences decrease.

2. The visual cues play an important role in the behavioral organization of the subjects of the older three age groups. The random displacement of visual cues disturbs them and increases the incorrect sequences variability. This disturbing effect diminishes as age increases.
   On the contrary, the visual cues do not seem to influence the behavior of the 5-6 y.o., who are the best performers and the most stereotyped with the random matrix R.
   The analysis of the types of dominant sequences used by subjects and of their distributions can help in evaluating the role of visual cues and their influence on the sequence form. On one hand, 100 % of 5-6 y.o. prefer to produce the diagonal sequences in R and also, with the other matrix types. In fact, the use of such a motor strategy allows them to conclude correctly a sequence without any comprehension of

the movements of the visual cues. On the other hand, older subjects also use the two diagonal sequences as an adapted strategy in R. But, when visual landmarks are available, these subjects - contrarily to the 5-6 y.o. - prefer to use the corner sequences and the other correct sequences. The corner sequences seem easier to follow visually on the matrix. The use of these sequences indicates that the subjects understand the relation between their responses and the movements of the visual cues . It is an optimal strategy to maximize outcome when confronted to the normal matrix. This could also be the case of the diagonal sequences, but for the three older groups, the visual feedback plays an important role in the choice of responses. They do not produce combination of motor responses but "ways" to reach the goal-window.

3. Results indicate that it is possible to induce behavioral variability. When reinforcement contingencies demand it, adults and adolescents produce much more variability (even a little more than what is required). It revealed more difficult to induce correct variability among the 9-10 y.o. and, particularly, among the 5-6 y.o.
It seems that the low performance of these last subjects cannot be attributed only to an incomprehension of the variability requirement (their variability is slightly higher in D than in N) and to the intermittence of reinforcements (by-product of the decrease of the number of reinforcements). *It seems to be tied with the incapacity to* master the rules (notably, the incapacity to master the visual informations to produce other correct sequences than corner or diagonal sequences).
Results of an experiment carried out by BOULANGER (1986), support this hypothesis. This author presented to subjects o 5-6 y.o., 9-10 y.o. and 14-15 y.o. a task (the Pyramid task) the basic principles of which were similar to those of the Visual Matrix task. The main difference consisted in the fact that all the combinations of 6 responses were available (there is not a maxima of three responses on each button). There were 64 different sequences and no incorrect sequence. The bank building wasreplaced by an Egyptian pyramid.
Three different types of situation were used :
1) Normal pyramid : All the sequences were reinforced.
2) Lag pyramid : A sequence was reinforced if it was different from the 10 previous ones.
3) Yoked control pyramid : Each subject belonging to this group was paired with a subject of the Lag pyramid group. These subjects received the same number of reinforcements, in the same order, independently of the sequences they had chosen to produce.
The results indicated that during the first session, the mean Uncertainty for children (5-6 y.o.) of the Yoked group was approximatively equal to that for children of the Lag group. The difference between Lag and Yoked control group increased with age (the mean Uncertainty for 14-15 y.o. of the Lag group was significantly higher than that for 14-15 y.o. in the yoked group)

while the difference between Yoked and Normal group decreased (the mean Uncertainty for children of the Yoked group was higher than that for children in the Normal group). During the second session, the Uncertainty for children of the Yoked group was clearly lower than that for children of the Lag group and it was equal to that of the children of the Normal group.
As noted by BOULANGER (1986), from the comparison between the results obtained with the pyramid and those obtained with the matrix, we can say that youngest subjects do preceive the contingencies of reinforcement and the necessity to vary (even if it is more slowly than the older subject) and that the higher variability of the Lag group (or in the matrix D) is not a by-product of the intermittence of reinforcements but seems to be operant variability proper.

4. A previous experience of reinforcement has a falicitation effect on the performance in R, for adults, adolescents and, particularly, for the 9-10 y.o., showing that visual cues coherence is less important when subjects have already awareness of reinforcement rules The reverse effect is observed for the 5-6 y.o.; this could hypothetically be related to a general lack of plasticity among these young children. During the training, they could have incidentally learned the coherent relation existing between thedisplacements of visual cues and the reinforcement. So, they could have difficulty leaving this relation out of account when the situation has been modified and to change their behaviors in consequence.
A previous exposure to N does not prevent adults and adolescents from adopting a more variable behavior when contingencies require it, and a greater variability during previous exposures tends to increase the variability in the normal situation (proactive effect of the variability "training").

In short, parallel to the increase of the performance and of the variability with age, it seems that the capacity to adopt adapted behaviors (more or less variable, but efficient) to the present environmental contingencies, also increases as a function of age. This capacity appears low among the youngest subjects. It begins to appear among the 9-10 y.o. (they are sensitive to the variability constraint, but they do not vary their behaviors in an optimal way; they have difficulty leaving the visual cues out of account in R. The observation of these subjects in R, has shown that they try to find a coherent relation between the displacement of visual cues and their pushes on the buttons). On the other hand, the capacity to differentiate one's behaviors is well developed among adolescents and adults. The older subjects tend to better optimize their behaviors, according to the present situation (more stereotyped in N and in R, when variability is not necessary for reinforcement; more variable if variability must be produced).

5. The results relative to the cognitive tasks reflect the capacities of "abstractness" as well the "mobility of thought", specific to each age group. Classification tasks (successive dichotomies and successive multiplicative classifications) show that mobility of thought and capacities of anticipation and of "abstractness" (in other words, the subjects' capacity to consider all the possible criteria of classification, the capacity to successively modify their arrangement according to these criteria, and the capacity to take simultaneously into account two criteria of a same element) increase as a function of age (5-6 y.o; to 14-15 y.o;). Seriation tasks give the same results, for the 5-6 y.o. and the 9-10 y.o.

   This parallel evolution of operative capacities in two of the elementary logical structures (classification and seriation) confirms, as expected, what has been described by Piaget and Inhelder (1967).

   The acquisition of these capacities is typical of the subjects' accession to the concrete operative stage, as does the comprehension of the inclusion quantification (the quasi-totality of our 9-10 y.o. subject understand it).

   The performances obtained with the perceptual serial classification task confirm these observations (the 9-10y.o. are able to consider simultaneously several classification criteria, while this is the case only for a few exceptional subjects of 5-6 Y.O. (only 10.40% of the *5-6 y.o. subjects have succeeded the 3 perceptual serial* classifications, compared to 40.70% of the 9-10 Y.O. subjects).

   Classification task of Level II indicates that the mobility of thought still increases among the 14-15 y.o. But the non-perceptual serial classification task shows that it stays at a similar level among adults.

   Adults and adolescents differ in the permutation task. Adults are better performers in this formal type task, implying the capacity to make operations on operations and the capacity to consider in thought all the possible combinations (combinatory operations). Adolescents would not sufficiently master the formal logic to take into account the totality of the possible relations between the elements of a system (however, as noted before, this difference between adults and adolescents could not only be explained by an effect of age).

   With regards to the cognitive style, the 14-15 y.o. are more field dependent than adults. In the two age-groups, females are more field dependent than males. The analytic attitude in a problem solving task would be more developed among adults and, particularly, among males.

Within each age group, subjects have been differentiated according to their cognitive capacities (and according to their cognitive style for adolescents and adults). However, no matter which age group is considered, no difference is found in performance and variability at the Visual Matrix task (with N in first session), as a function of the subjects' cognitive capacities or, for the adolescents and adults, as a function of cognitive style).

This experiment leads to consider behavioral variability as an inherent dimension of behavior, sensitive to contingencies of reinforcement, just like any other dimension of behavior.

Moreover, it suggests that the capacity of adaptation is function of the potentialities for variation. These potentialities themselves depend on the mastery of a set of basic behavioral units. The capacity to vary his behavior and to master the functioniong rules (in the case of the tasks used) is limited by the subject's general developmental level but it cannot be confounded with the subject's cognitive style or the subject's "mobility of thought".

CHAPTER 5

- EFFECT OF A VARIABILITY TRAINING ON THE SUBJECTS' ADAPTATION IN A NEW SITUATION

- VARIABILITY AND EDUCATIONAL BACKGROUND

- EXPERIMENTS 2 AND 3 -

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5.1. EXPERIMENT 2

5.1.1. AIMS OF EXPERIMENT 2

The first experiment has confirmed and further documented the observations made in previous similar works concerning the emergence of stereotyped behavior as a function of the number of trials.

It has also shown that, when reinforcement contingencies demand it, adults and adolescents produce much more variability, and that a greater variability induced by a previous exposure to favourable conditions (matrix D) seems predictive of high variability in the normal situation when this is reinstated later on.

These results would suggest that a training that would induce the subjects to produce a very variable behavior (as opposed to a training that would lead to stereotyped behavior), would facilitate the subjects' adaptation to situations where they would have to modify their behavior in order to solve a problem.

As noted in Chapter 2.4, it could also be hypothetized that some socio- cultural factors would have effects on behavioral variability.

In the first experiment, it had been hypothetized that some cognitive factors (as "mobility of thought "or "field-dependence/independence") could be related to the performance and the variability in the Visual Matrix task.

This hypothesis has not been confirmed by the results. This could be due to the particular aspects and measures of cognitive capacities and styles that have been used. It seemed advisable to verify if the lack of relation between these cognitive factors and the behavior in the Visual Matrix task was confirmed when another type of matrix situation was taken into account and when another type of population was concerned.

In summary, the following questions were considered :

1. To what extent can subjects vary their behavior to adapt themselves to a situation that requires variability ?
2. Does variability training facilitate the subjects' adaptation in a situation in which only three sequences (among the twenty correct sequences available) are reinforced ?
3. Are the subjects' behaviors different depending upon their type of educational background on one hand, and their "mobility of thought" and cognitive style, on the other hand ?

5.1.2. METHOD

5.1.2.1. Subjects :

53 male subjects were selected and distributed into two age groups :

1. Technical School adolescents - 3th grade - (n=31) ranging in age from 14-3 to 16-1, with a mean of 14-11 years of age. The subjects were issued from two schools for manual workers (electro-mechanics).
2. Adults subjects (n=22) ranging in age from 18-4 to 23-5 with a mean of 21-4 years of age. They were issued from an industrial training center (training for lathe operators and metal fitters). All these subjects had previously received the same training in the same type school as the adolescents, before being trainees at the industrial training center.

5.1.2.2. Materials and procedures :

- Visual Matrix task :

Four matrix types were used : Normal Matrix (N); 2 matrixes with differential reinforcement (D and D_{10}) and Matrix with prescribed sequences (C) (see description pp).

Subjects of each age group were randomly distributed into two experimental groups and they were individually submitted to five sessions of 50 trials each, in their educational environment (two successive sessions on the first day and three successive sessions on the next day).

Subjects of our sample were distributed into the 2 experimental groups as showed in the Table 2.1.

Experimental groups / Age groups	N N N C N	N D D_{10}C N	TOTAL
ADOLESCENTS	15	16	31
ADULTS	11	11	22
TOTAL	26	27	53

Table 2.1 : subjects' distribution in each age group and in each experimental group.

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- Cognitive tasks.

Subjects of both age groups were individually submitted to the following tasks :

1. Non-perceptual serial classification task.
2. Group Embedded Figures test (GEFT) (field dependent/independent cognitive styles).

5.1.3. RESULTS

5.1.3.1. Visual Matrix task :

The ten indices selected to provide optimal information about performance and behavioral variability have been defined pp 81-83
Means and standard deviations of each index, for each experimental group, as a function of age and of session can be found in Appendix 2 (Tables 2.1 to 2.4, pp 72-75)
Like in experiment 1, Dominant Sequences (DS) distributions as a function of session and of age, in each experimental group, were analysed.

5.1.3.1.1. Effects of age and of session in each experimental group :

- *Student T-tests for related samples were used to compare the values of each index, along the 5 sessions, for the same experimental group and the same age group (see Tables 2.9 to 2.12 in Appendix 2, pp 80-83).*
- *Student T-tests for independent samples were used to compare the values of each index as a function of the two age groups, for the same session of the same experimental group (see Tables 2.13 and 2.14 in Appendix 2, pp 84-85).*

- Experimental group N N N C N

Figure 2.1. (p. 162) presents, for each index, mean values as a function of session, and for each age group, in the group NNNCN.

performance :

For all subjects, there is an increase of the %CS from the first to the third session, in which, they eventually reach a very high level of % CS(>90%).

The Matrix C produces a significant decrease of the performance (NSC (X2) indicates that the adults and the adolescents receive 46.36% and 47.33% of reinforcement, respectively). This low performance can be explained (especially for adults) by the increase in number of incorrect sequences on one hand, and by the number of trials which were necessary to find out one of the appropriate sequences, on the other hand. The %C.S. returns to a very high level during the last session.

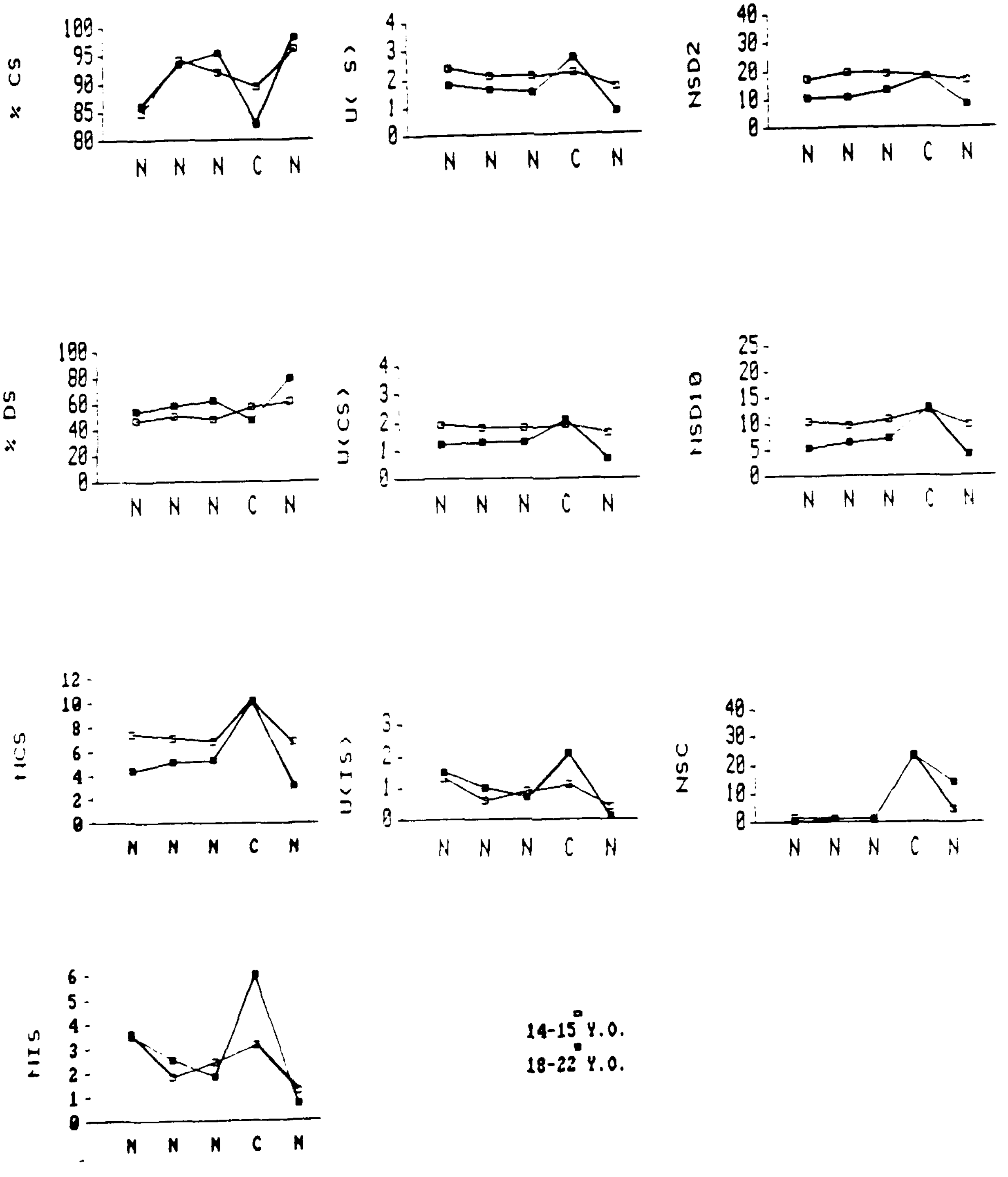

Fig. 2. 1. For each index, mean values as a function of session and for each age group, in the group NNNCN

variability :

Neither for adults nor adolescents, any significant modification of the correct sequences variability from the first to the third session is observed.

Parallel to the evolution of the performance (% CS) along the first three sessions, a significant decrease of the incorrect sequences variability is noted (NIS and U(IS)). For these sessions, adolescents have a slight tendency to be more variable than adults (significant only for NCS in the first session). Distributions of D.S. types are approximatively the same for adults and adolescents, in the three sessions. Corner sequences are choosen by the majority of subjects (Table 2.2, p. 164).

The Matrix C entails an increase of the variability of incorrect (NIS and U(IS)) and correct sequences (adolescents : significant for NCS; adults : significant for NCS and U(CS)).

These effects are much more pronounced for adults. So, having been placed in a situation that tends to induce stereotypy, the subjects adopt a more variable behavior in order to bring a solution to the task. The significant increase of NSC between the third and the fourth session indicates that, in general, subjects adapt themselves to the constraint of the task. Distributions of DS types in C support this view (Table 2.2). However, as mentioned earlier, the low performances indicate that they need much more trials to adjust themselves to the new constraints.

In the last session, the number and the variability of incorrect sequences are significantly lower than in the other sessions. Adults become more stereotyped than during the first three sessions. Adolescents keep a relatively constant level of variability as compared with the first sessions. In general, the variability indices and the distributions of D.S. types indicate that the majority of subjects keep a sufficient level of variability to perceive the possible modifications of the situation and to be able to change their D.S. if the situation requires it.

In short, while there is no difference between the 2 age-groups with regard to performance, adolescents tend to be spontaneously more variable and they seem less disturbed by the modifications of contingencies than adults.

AGE	D.S.	N	N	N	C	N
14-15 y.o.	1 Corner	11 73.3	8 53.33	7 46.66	1 6.6	6 40
	2 Diagonal	2 13.3	5 33.33	5 33.33	4 26.66	4 26.66
	3 Other	2 13.3	2 13.33	3 2.0	0	2 13.32
	4 Incorrect	0	0	0	0	0
	5 Constraint	0	0	0	10 66.66	3 20
ADULTS	1 Corner	7 63.6	6 54.54	5 45.45	0	5 45.45
	2 Diagonal	2 18.2	2 18.18	5 45.45	0	2 18.18
	3 Other	2 18.2	3 27.27	1 9.09	2 18.18	1 9.09
	4 Incorrect	0	0	0	0	0
	5 Constraint	0	0	0	9 81.81	3 27.27

Table 2.2 : Absolute and relative frequencies of D.S. types as a function of age and of session, in the group NNNCN.

- Experimental group $NDD_{10}CN$

Figure 2.2 (p. 165) presents, for each index, mean values as a function of session and for each age group in the group NDD_{10} CN.

performance :

The requirement of variability in D does not stop the increase of % CS. For both age-groups, this percentage remains constant for the sessions 3 and 4 and it increases again in the last session.

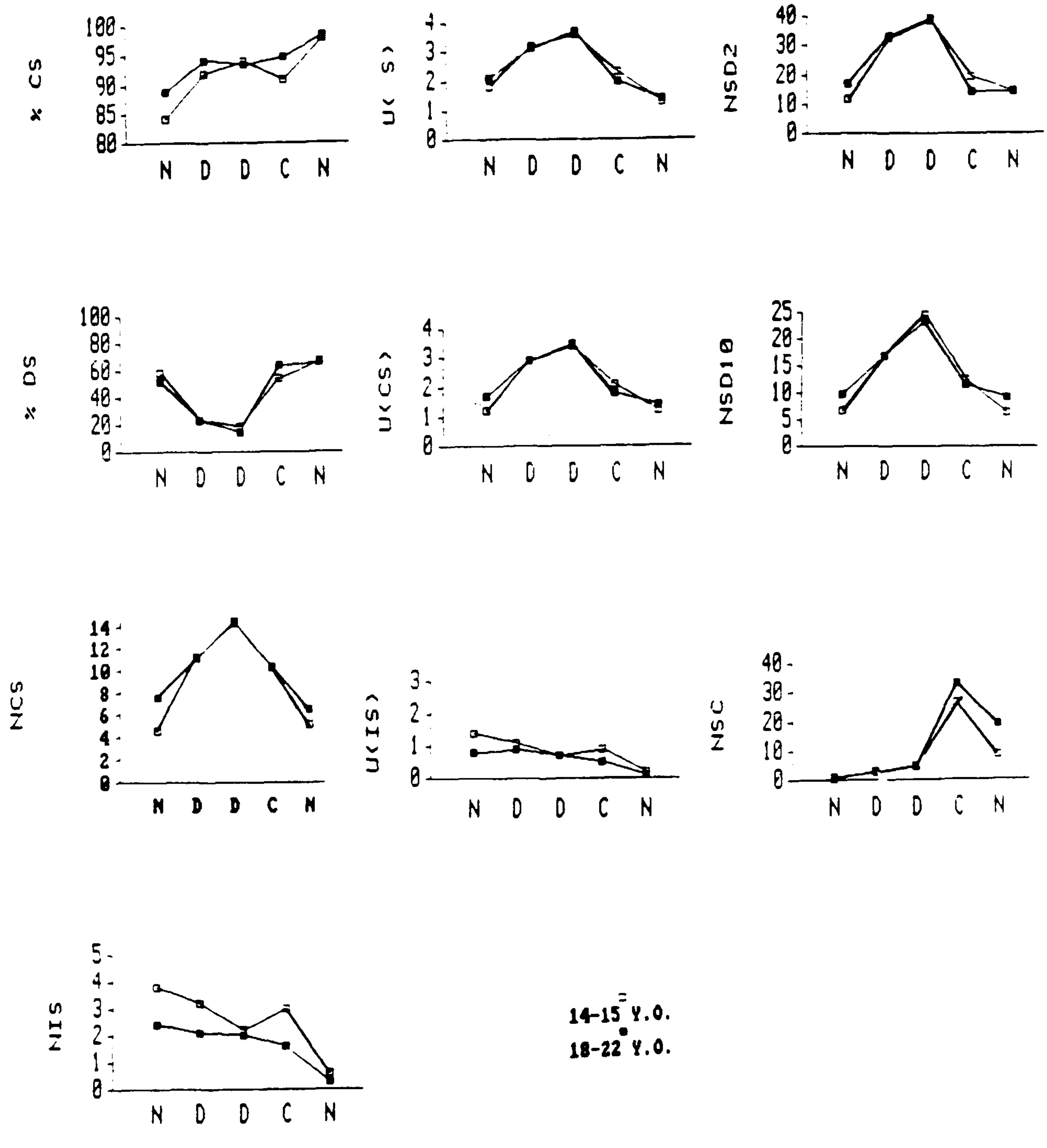

Fig. 2. 2. For each index, mean values as a function of session and for each age group, in the group $NDD_{10}CN$

Three other indices that correspond to the numbers of reinforcement in the matrices D, D_{10} and C must be taken into account here : the number of sequences differing from the two previous ones (NSD_2); the number of sequences differing from the ten previous ones (NSD_{10}) and the number of sequences corresponding to the 3 ones which are reinforced in C (NSC). These indices give, in fact, the real performance of subjects with D D_{10} and C, respectively, and they allow to assess their adaptation to the 3 Matrix types (Table 2.3).

	N	D	D10	C	N
14-15 y.o.	84	64.5	49.25	52.75	98.25
ADULTS	88.91	65.82	46.72	68.81	98.55

Table 2.3 : percentages of reinforcement as a function of session, for each age group, in the group $NDD_{10}CN$.

During the second session, there is a significant increase of NSD_2 for the 2 age-groups, but the percentage of reinforcement does not reach the value obtained with the Matrix N in first session.

The significant increase of NSD_{10} from the second to the third session suggest that the subjects have modified their behavior in order to adapt to the new reinforcement contingencies and that they are able to still more vary their behaviors. However, the percentages of reinforcement are lower than in D. This might indicate that subjects do not in fact understand the precise requirements of the task or that they do not use an appropriate strategy to ajust to the contingencies.

The significant increase of NSC in the fourth session indicates that subjects grasp the constraint of the Matrix C. It seems easier for them to adapt to this Matrix than to D_{10}. This seems particularly obvious for the adults. (However, the difference between the two age-groups is not significant).

For all the subjects, the performance reaches its maximum during the last session.

variability :

In this group, adults tend to be spontaneously more variable than adolescents. The difference observed in the other group, could be due to a sample effect. In each age group, when the values of indices in first session are computed for the totality of subjects of the two experimental groups (N global), no significant difference is found between the 2 age groups.

The Matrices D and D_{10} lead to a significant increase of general variability (U(S)), which can be explained for both age-groups by the increase of the variability of correct sequences (U(CS)). In D_{10}, subjects use near 75% of the possible correct sequences (U(CS)). We note a slight decrease of the variability of incorrect sequences (no-significant). There is no significant difference between adults and adolescents with regard to their adaptation to variability requirements.

The Matrix C leads to a reduction of the general variability (%DS and U(S)) up to its initial level (in first session). However, the number of different correct sequences stays significantly higher in the fourth session than in the first one. This probably reflects the variability which is necessary if a subject is to find out one of the three possible correct sequences.

With regard to DS (Table 2.4, p. 168), the Matrix D does not entail significant modification of the distributions of D.S. types : in the two age-groups, the majority of subjects prefer diagonal sequences as D.S., like in the first session. In D_{10}, the "other" sequences are chosen by a larger number of subjects as it was in D. In C, 90.91% of adults and 75% of adolescents choose as D.S., one of the three possible sequences. It confirms that the great majority of subjects eventually adapt to the constraint of this Matrix.

During the last session, the variability of correct sequences decreases to reach the same level as in the first session. The Matrix C has a proactive effect on the distribution of DS types : 45.45% of adults and 12.5% of adolescents continue to produce in the last session, the same sequence as in C.

AGE	D.S.	N	D	D_{10}	C	N
14-15 y.o.	1 Corner	10 62.5	8 50.0	7 43.75	1 6.25	7 43.75
	2 Diagonal	3 18.8	5 31.25	2 12.5	2 12.5	6 37.5
	3 Other	3 18.8	3 18.75	7 43.75	0	1 6.25
	4 Incorrect	0	0	0	1 6.25	0
	5 Constraint	0	0	0	12 75.0	2 12.5
ADULTS	1 Corner	8 72.7	8 72.72	3 27.27	0	1 9.09
	2 Diagonal	2 18.2	0	2 18.18	0	4 36.36
	3 Other	1 9.1	3 27.27	6 54.54	1 9.09	1 9.09
	4 Incorrect	0	0	0	0	0
	5 Constraint	0	0	0	10 90.91	5 45.45

Table 2.4 : Absolute and relative frequencies of D.S. types as a function of age and of session, for each age group, in the group $NDD_{10}CN$.

5.1.3.1.2. Comparison of the pretrained subjects' behaviors as a function of Matrix Type and of Age

The results obtained by subjects pretrained in N with the matrixes N and D in the second session were compared. Figure 2.3 (p. 169) presents mean values of performance and variability indices as a function of age and of matrix type, in the second session.

For each index, Two - Way ANOVA (age X matrix type) in the second session (see Table 2.15 in Appendix 2, p 86) was only completed by Student T-tests (matrix type) for each age group (see Table 2.16 in Appendix 2, p 87) because Two-Way ANOVA revealed no effect due to age.

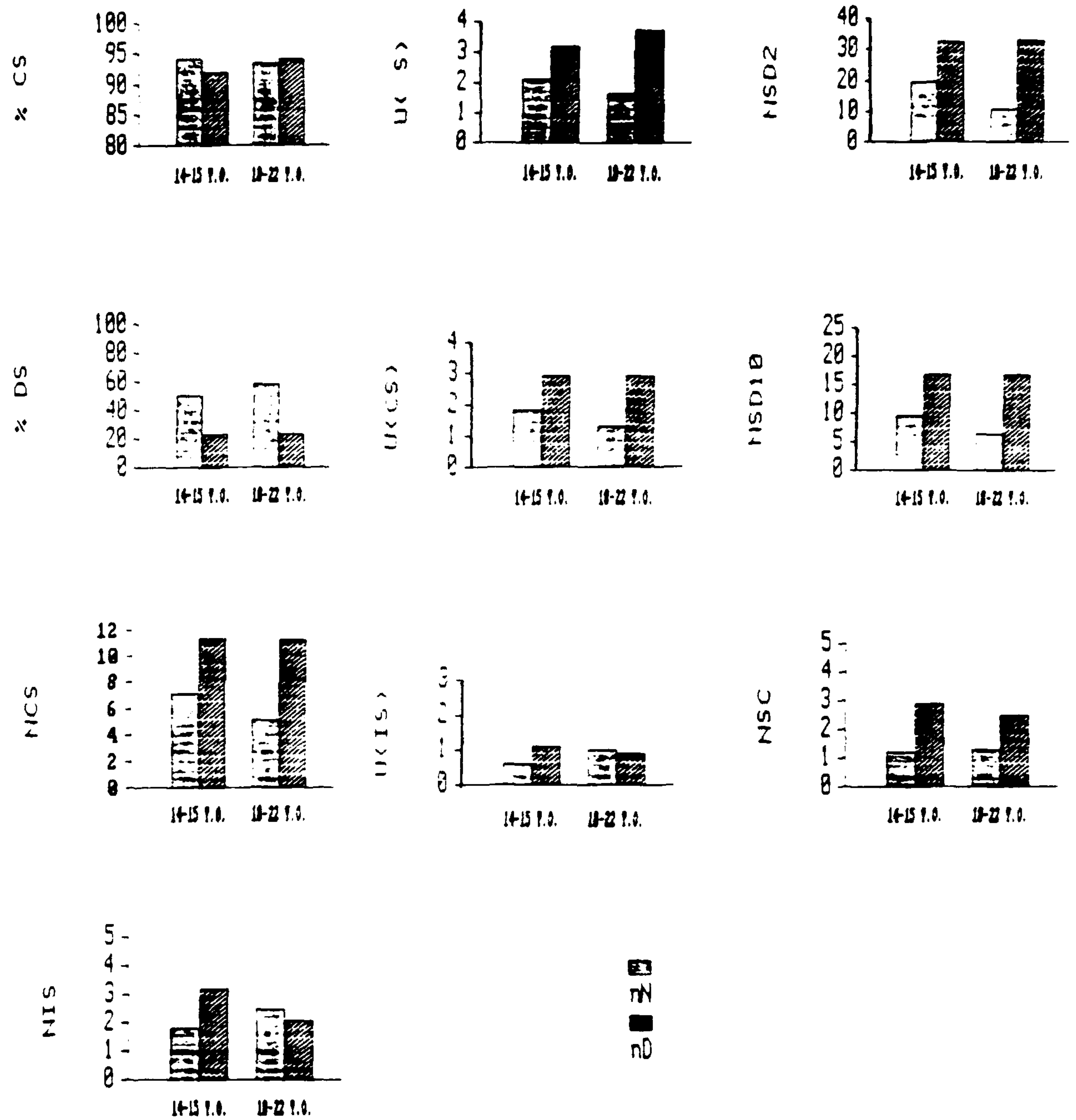

Fig. 2. For each index, mean values as a function of age and of matrix type (N and D),in the second session (lower case letters are used as symbols for first session condition, capital letters for second session condition)

Results show that adults and adolescents are equally sensitive to particular contingencies of reinforcement. They are able to adopt more variable behavior when experimental contingencies require it. The global variability(with regards to %DS and U(S)) is larger with D, and this can be explained by the importance of the variability of correct sequences (U(CS), NCS). They adapt to the requirement of variability (NSD_2 is higher in D than in N) and this contingency does not significantly influence the %CS. However, it does not allow subjects to reach the same performance in D than in N (94.27% and 93.45% of reinforcement in N; 64.50% and 65.82% of reinforcement in D, for the 14-15 y.o. and for adults, respectively). This fact indicates that the understanding of the task in D is not easy for some of the subjects or - at least- that they need many trials to adapt to it. The DS are not significantly differently distributed according to Matrix type (Table 2. 2, p. 164 and Table 2.4, p. 168). In D as in N, the majority of the subjects prefer corner sequences as DS. Even if there is no significant difference according to age, 14-15 y.o. show a slight tendency, in D and in N, to prefer diagonal sequences as DS.

The comparison of results obtained with the Matrixes N and D_{10} in the third session was doubtful : the effect of the factor "Matrix" could be assigned both to particularities of the Matrix in itself and to the type of pre-training received by the subjects. The effect of age was the only one which could be taken into account and Two-way ANOVA did not reveal any effect of age. Concerning behaviors observed with the Matrix D10, we refer to our first analysis (effects of session and of age in the group $NDD_{10}CN$, pp 164-168).

5.1.3.1.3. Effects of pre-training :

- Effects of pre-training on behavior in C (fourth session) :

Figure 2.4 (p. 171) presents mean values of performance and variability indices as a function of age and of type of pre-training, in C. No matter which index is considered, Two-way ANOVA (age x pretraining) does not reveal any effect of age. (see Table 2.17 in Appendix 2 p.88). The effect of pre-training is significant only for U(I.S.); so, at first sight, the only effect of a variability training is to entail a reduction of the variability of incorrect sequences. However, comparisons of behaviors in C according to the type of pre-training inside each age-group, allow us to note some tendencies. (Student T-tests (pre-training) : Table 2.18 in Appendix 2 p.89).

In both age-groups, the variability training has no effect on the variability of correct sequences. However, for adults, particularly, variability training seems to facilitate the performance in C. This increase of performance can be attributed to the number of incorrect sequences which is lower after the variability training than after the pre-training with N. To explain this effect, it can be suggested that subjects who received a variability training did not directly perceive the modification of the contingencies. Therefore, they continued to vary as before. Doing

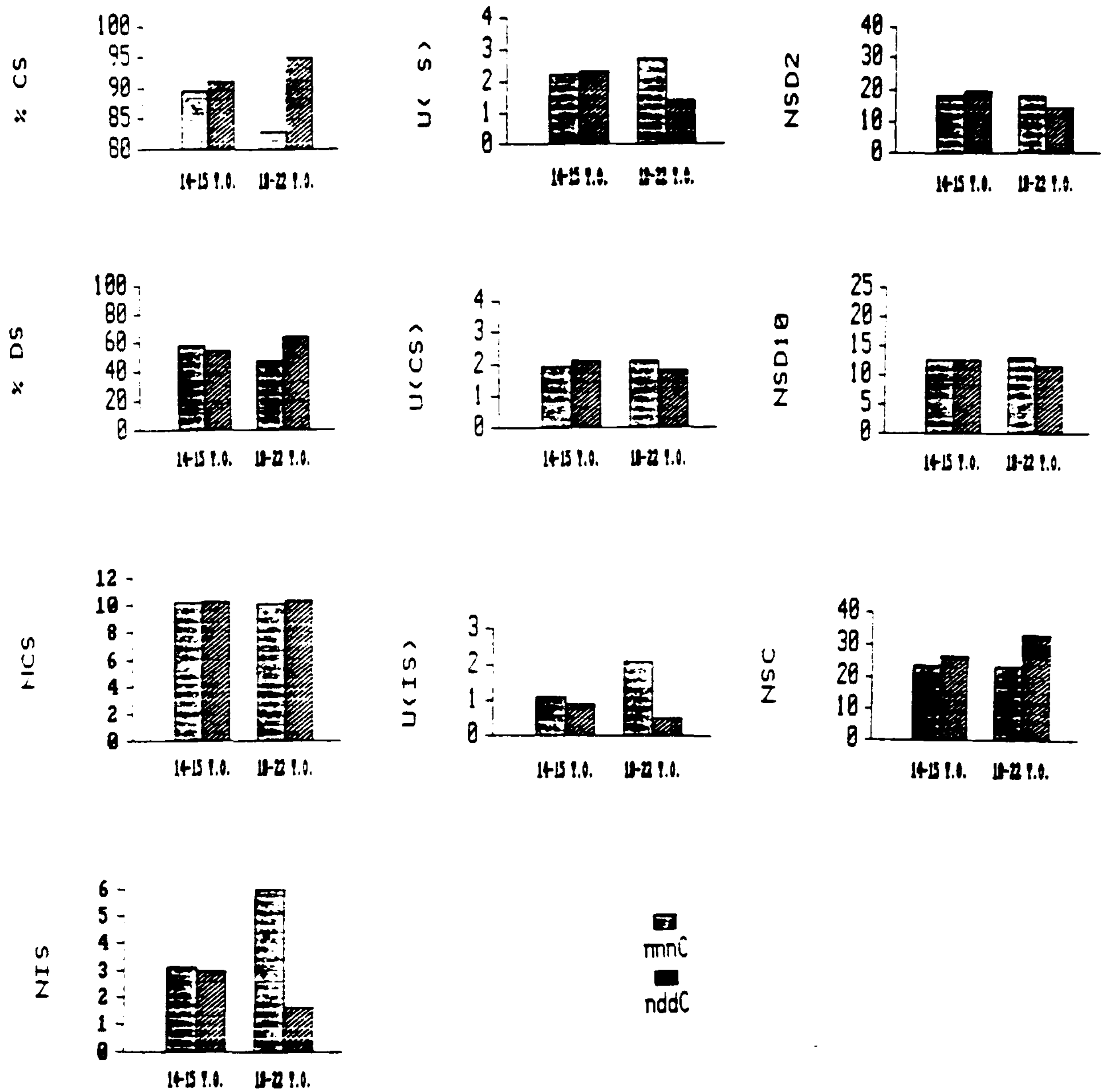

Fig. 2. 4. For each index, mean values as a function of age and of pre-training type, in the fourth session (C) (lower case letters are used as symbols for first three sessions conditions, capital letters for fourth session condition)

so, they had a higher probability to do one of the 3 reinforced sequences than other subjects.

For adolescents, the variability training has no effect. Even, it can be thought that some of them did not perceive at all - or have perceived later than adults - the modification of the contingencies. Distributions of DS support this hypothesis, even if the majority of subjects use a "constraint" sequence as DS in C (Table 2.4, p. 168).

- Effects of pre-training on behavior in N (last session).

Statistical analysis does not reveal any effect of pre-training neither on the performance nor on the variability in N during last session. (Table 2.19 in Appendix 2 p.90).The effect of age is significant only for N.S.C.: during the last session (in the 2 experimental groups). The adults use the sequences which are reinforced in C, more often than the 14-15 y.o.

5.1.3.1.4. Effects of type of educational background on performance and on behavioral variability

Results obtained by the subjects of this experiment ("Technical population" : T) were compared with the ones obtained by the subjects of the same age groups (adolescents and adults) of experiment 1 ("General population" : G)

For recall, adolescents in experiment 1 were students in General Secondary Schools (as opposed to subjects of this experiment who came from schools for manual workers) and adults in experiment 1 were University students (contrary to adults of this experiment who were trainees at an industrial center). The level of the educational trainings in this experiment is inferior to the one of the subjects of the experiment 1.

- Performance and variability in N, in first, second and third sessions.

For N in first session, we have gathered the results of subjects who have received N in first session, in each population and in each age-group. (subjects from experimental groups NNN, NRN and NDN, for the G population -i.e. 56 adolescents and 61 adults- and subjects from the 2 experimental groups NNNCN and $\underline{N}DD_{10}CN$ for the T population i.e. : 31 adolescents and 22 adults).

For N in second and in third sessions, we have taken into account the subjects from the experimental group NNN for the G population (17 adolescents and 21 adults) and the subjects from the experimental group NNNCN for the T population (15 adolescents and 11 adults).

The figure 2.5 (p. 173), presents mean values of performance and variability indices as a function of age and of type of study, in N in first, second and third sessions.

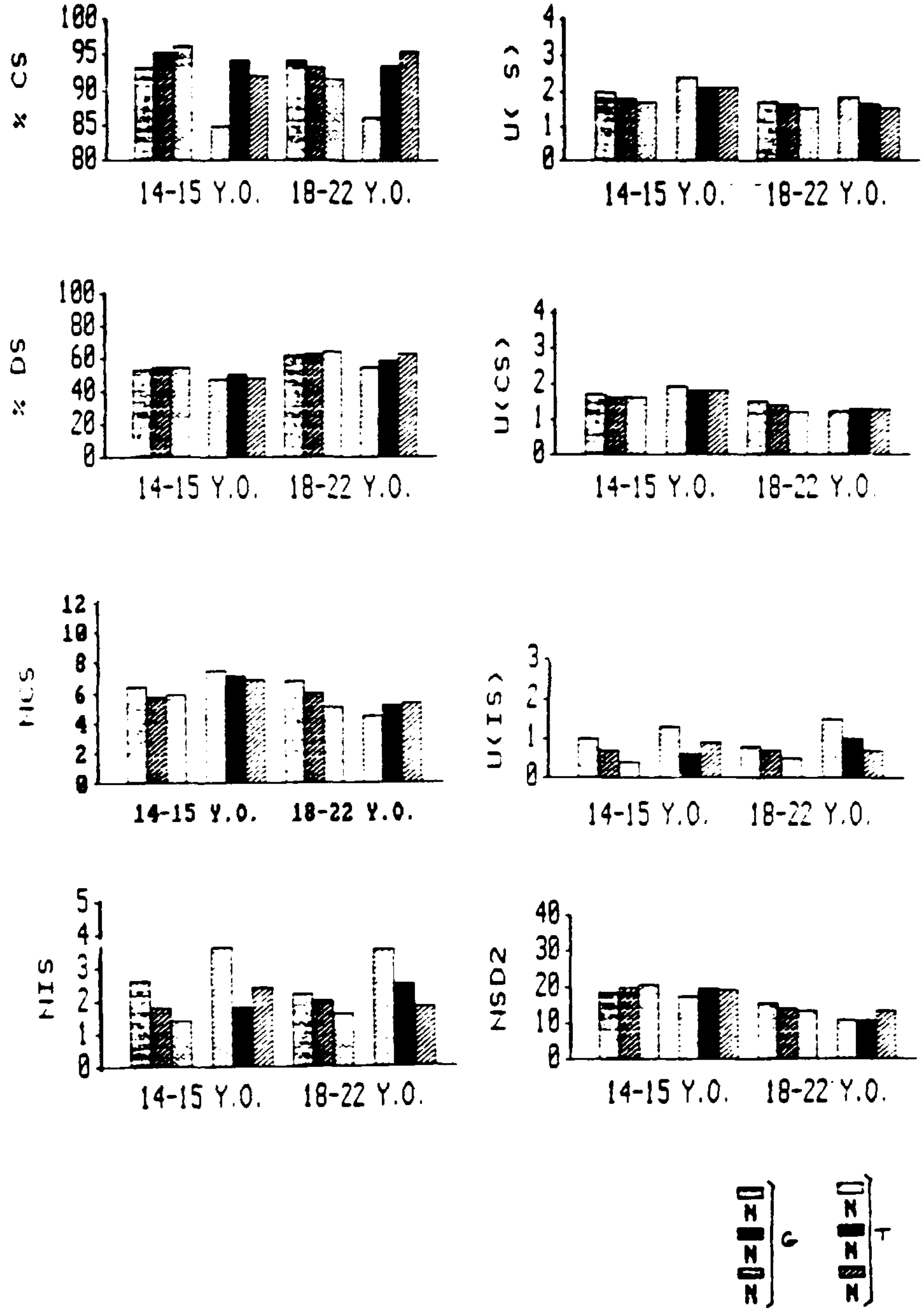

Fig. 2. 5. For each index, mean values as a function of age and of school education, in N in first, second and third sessions (G = "General population", T = "Technical population")

Means and standard deviations for each session of the group NNN and for the first two sessions of the group NDN, for each age group of the population G, can be found in Appendix 2 (Tables 2.5 to 2.8, pp 76-79).

For each index, Two-Way ANOVA (age X study) in N (1th, 2th and 3th sessions) (see Table 2.20 in Appendix 2, p 91) was completed by Student T-tests (type of study) for each age group (see Table 2.21 in Appendix 2, p 92).

The differences of behavior related to the type of educational background are significant only for the % CS, NIS and U(IS) in first session.
In both age groups, the subjects of the T population have performances significantly lower than performances of the subjects of the G population and the variability of their incorrect sequences is higher. On the contrary, there is no difference between the two populations with regard to the variability of correct sequences.

The DS are not significantly differently distributed according to the type of educational background. In each age-group and in each population, the subjects prefer corner sequences (Table 2.5).

POPULATION		T			G		
AGE	D.S	N GLOBAL	N	N	N GLOBAL	N	N
	1 Corner	21 67.74	8 53.33	7 46.66	44 78.57	12 70.58	12 70.58
	2 Diagonal	5 16.13	5 33.33	5 33.33	4 7.14	2 11.76	2 11.76
14-15 y.o.	3 Other	5 16.13	2 13.33	3 20.0	8 14.28	3 17.64	3 17.64
	4 Incorrect	0	0	0	0	0	0
	5 Constraint	0	0	0	0	0	0
	1 Corner	15 68.18	6 54.54	5 45.45	44 72.13	13 61.9	13 61.9
	2 Diagonal	4 18.18	2 18.18	5 45.45	9 14.75	4 19.04	4 19.04
ADULTS	3 Other	3 13.63	3 27.27	1 9.09	8 13.11	3 14.28	4 19.04
	4 Incorrect	0	0	0	0	0 4.76	1
	5 Constraint	0	0	0	0	0	0

Tab. 2.5 : absolute and relative frequencies of DS types as a function of session (NNN), for each type of population and for each age group.

- Performance and variability in D in the second session (Subjects pre-trained in N)

Subjects from the experimental group NDN for the G population (19 adolescents and 20 adults) and subjects from the experimental group $NDD_{10}CN$ for the T population (16 adolescents and 11 adults) have been taken into account. Figure 2.6 (p. 176) presents mean values of performance and variability indices as a function of age and of type of study, in N in first session and in D in second session.

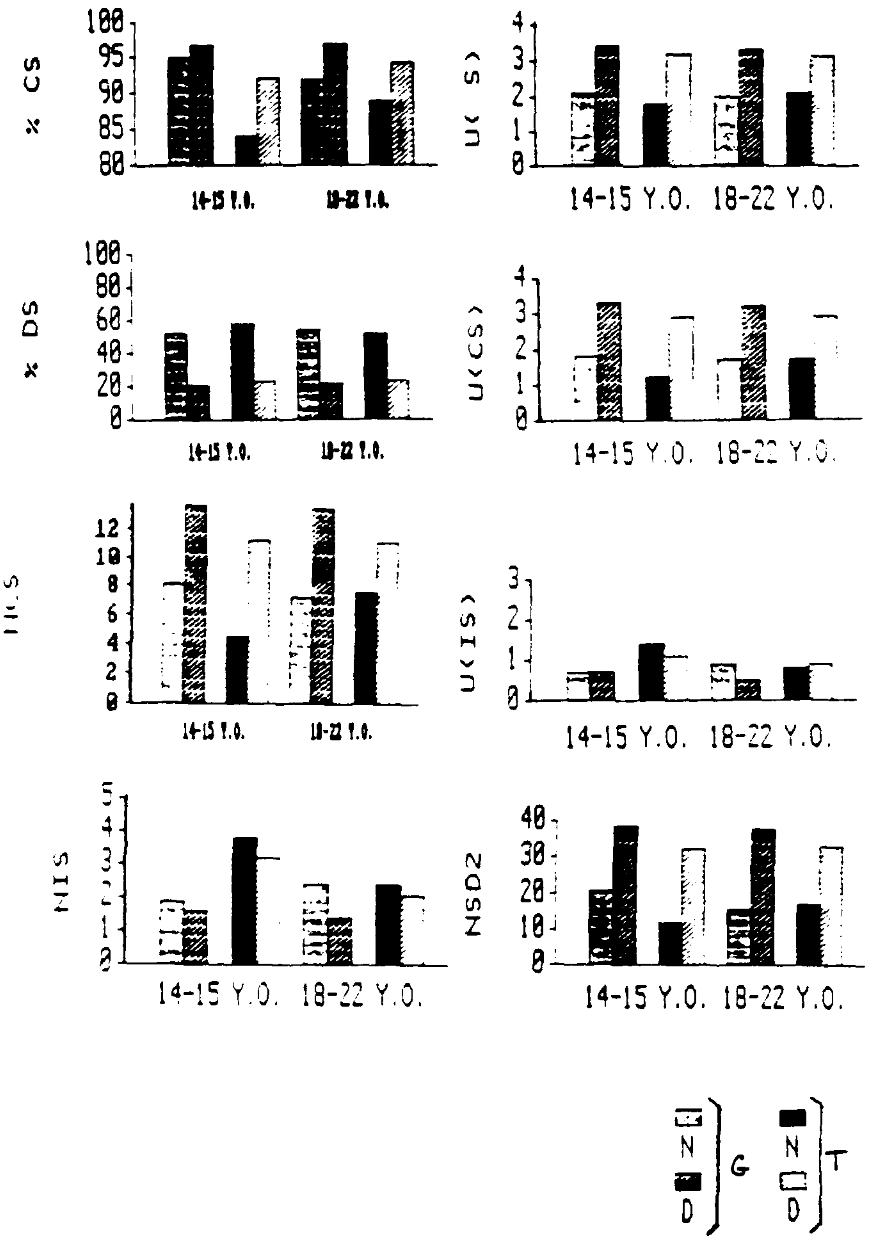

Fig. 2. 6. For each index, mean values as a function of age and of school education, in N in first session and D in second session (G = "General population"; T = "Technical population")

For each index, Two-Way ANOVA (age X study) in D (2th session) (see Table 2.22 in Appendix 2, p 93) was completed by Student T-tests (type of study) for each age group (see Table 2.23 in Appendix 2, p 94).

There is a significant effect of the type of educational background both on the performance and variability indices . The subjects of the T population have a performance inferior to the one of the subjects of the G population (NSD_2). They are less variable with regard to correct sequences (NCS and U(CS)) and the number and the variability of their incorrect sequences (NIS and U(IS)) are higher than those of the subjects of the G population.

The differences between the 2 populations are more pronounced for adolescents than for adults.

The DS are not significantly differently distributed as a function of the type of educational background (Table 2.6).

	POPULATION T		POPULATION G	
D.S.	14-15 y.o.	ADULTS	14-15 y.o.	ADULTS
1 Corner	8 50.0	8 72.72	12 63.15	11 55.0
2 Diagonal	5 31.25	0	1 5.26	2 10.0
3 Other	3 18.75	3 27.27	6 31.57	7 35.0
4 Incorrect	0	0	0	0

Table 2.6 : Absolute and relative frequencies of D.S. types for each type of population and for each age group, in D in second session

5.1.3.2. Cognitive tasks :

5.1.3.2.1. Description of results for each cognitive task as a function of age and of educational background :

- Non-perceptual serial classification task :

NUMBER OF CORRECT ITEMS	G POPULATION 14-15 y.o. n = 56	G POPULATION ADULTS n = 61	T POPULATION 14-15 y.o. n = 30	T POPULATION ADULTS n = 22
0-2	8 14.3	3 4.9	0 0.0	1 4.5
3-4	18 32.1	22 36.1	7 23.3	6 27.3
5-6	30 53.6	36 59.0	23 76.7	15 68.2

Table 2.7 : For each type of population and for each age group, absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of correct items at the non-perceptual serial classification task)

Table 2.7. shows that no matter which population is analysed, no significant difference is found between the adolescents' and adults' distributions. In both age-groups subjects of the T population perform at an higher level than subjects of the G population. The difference is significant for the 14-15 y.o. only ($X2 = 6.49798$, $df = 2$; $p = .038$). These results are opposite to what would have been expected, after the results obtained by Botson (1976). However, it can be suggested that the educational background of the subjects of the T population could have favoured partially the thought process involved in this task. In the non-perceptive serial classifications, the task of the subjects is to complete series of objects by inserting, at a given point, the appropriate object (selected among an array of 6 objects). At any point, the series can be dichotomically cut, with objects on one side sharing a common property, but lacking an additional property shared by the objects on the other side. In order to solve the problem, subjects must be able to take into account simultaneously several criteria of dichotomy, and to integrate all the relations existing between the elements of a series. This implies that subjects have the capacity to analyse the different perceptive characteristics of each object. This type of process seems to be easier for subjects of the T population than for subjects of the G population. For the latters, some criteria of dichotomy are not perceptually obvious (for

example, the transparence of objects, as opposed to color). On the contrary, subjects of the T population seem to have met less difficulty in perceiving these characteristics. It could be explained by the type of specific training they are given during their studies (they are invited to manipulate and to analyse the different physical characteristics of objects more often than the subjects of the G population).

- Group Embedded Figures Test (GEFT) :

	G POPULATION		T POPULATION	
NUMBER OF CORRECT ITEMS	14-15 y.o. n = 56	ADULTS n = 61	14-15 y.o. n = 29	ADULTS n = 22
0-12	32 57.1	19 31.1	14 48.3	2 9.1
13-16	17 30.4	23 37.7	12 41.4	8 36.4
17-18	7 12.5	19 31.1	3 10.3	12 54.5

Table 2.8 : For each type of population and for each age group, absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of correct items at the GEFT)

Table 2.8 shows that in the two populations, adolescents are significantly more field dependent than adults (G population : X^2 = 9.55596, df = 2; p =.008; T population : X^2 = 14.51262, df = 2; p = .0007). There is no significant difference between the two populations. However, subjects of the T population (mainly, the adults) tend to be more "field-independent" than subjects of the G population.

5.1.3.2.2. Relations between cognitive tasks

It is only when the totality of the subjects (populations and age-groups blended) is taken into account that the number of correct items of the serial classification is positively correlated to the number of correct items of the GEFT (ρ =.2733, p < .001).

5.1.3.2.3. Relations between cognitive tasks results and performance and variability indices (Matrix Task).

For each age-group in each type of population, there is no significant relation between the cognitive tasks results and the performance and variability indices (no matter which matrix type is considered) (same statistical analysis as in experiment 1).

So, as it was noted in experiment 1, it seems that there is no relation between behavioral variability on one hand, and the subjects' field-dependence/independence or their cognitive capacities as the mobility of thought, on the other hand (as assessed by the cognitive tasks used).

5.1.4. CONCLUSIONS OF EXPERIMENT 2

In this experiment, the following questions were considered :

1. To what extent can subjects vary their behavior to adapt themselves to a situation that requires variability ?
2. Does a variability training facilitate the subjects' adaptation in a situation in which only three sequences are reinforced ?
3. Are the subjects' behaviors different depending upon their type of educational background on one hand, and their "mobility of thought" and cognitive style, on the other hand ?

Main results are as follows :

1. Globally, adolescents' behaviors are not different from adults' behaviors with regard to each Matrix type. Subjects' behaviors show that they are sensitive to environmental factors : they are able to modify their behavior as a function of the Matrix type.

   In the normal situation (N), subjects have a good performance and the contingent reinforcement produces some stereotypy. However this last one remains relatively constant throughout the three sessions and the subjects keep always a certain level of variability (they always make several different correct sequences).

   When reinforcement contingencies demand it, subjects produce more variability, even more than what is required (when the request of variability is not too important, as in D). The majority of them are able to adapt themselves to this requirement.

   When the task requires much more variability (D_{10}), subjects vary still more their behaviors. The level of variability that they reach, is theoretically sufficient to allow them to meet these contingencies. However, the low percentage of reinforcement let us think that subjects do not adopt an appropriate behavior in order to adapt to the precise contingencies of the task. The analysis of the 50 sequences emitted by some subjects of the group $NDD_{10}CN$ in the third session, let think that they do not vary their sequences in a systematic way).

2. Even when they have been put in a situation which entails stereotypy, subjects are able to modify and to vary their behaviors in order to adjust to a modification of the contingencies (Matrix C). The low performance reflects mainly the large number of trials which are necessary to find an appropriate sequence. In adults, a variability training entails a slightly better performance when precise behaviors are required from the subjects (C). It can be thought that the subjects who have received this training have not directly perceived the modification of the

contingencies. Therefore, they have continued to vary as before and, doing so, they had a higher probability to emit one of the three appropriate sequences more rapidly than the subjects of the other experimental group.

The type of pre-training has no effect on the performance and the variability in the last session; however, some subjects continue here to use one of the three "constraint" sequences.

3. The adaptation to the task seem to be tied to the type of educational background : subjects who were following a technical training (in a Technical Secondary School or in an Industrial Training Center) have needed more trials to reach the same performance than the subjects who were following a General Educational cycle (In a General Secondary School or at the University level).

As to behavioral variability, the spontaneous variability level (as assessed by the Matrix N) does not seem to be tied to the type of educational background. But it is not easy to induce correct variability among subjects of the "Technical Population". While they are able to adopt a more variable behavior when contingencies require it, they do not reach the level of performance scored by the subjects of the "General Population". This difference can not be explained by their incapacity to adopt a more variable behavior (they are more variable in a situation which requires much more variability (D_{10}) but it could be due to the greater difficulty they have to adopt a consistent behavior.

This difference cannot be put in relation with the cognitive style or with the "mobility of thought" of the subjects of each type of population.

In each type of population, subjects have been differentiated as a function of their cognitive capacitites. However, no matter which type of population is considered, no difference is found with regard to behaviors in the Visual Matrix task (with each type of Matrix) as a function of the subjects' "mobility of thought" or "field dependence/independence".

In summary, refering the specific questions raised initially, results of this experiment ha e showed that :

1. The subjects are able to adopt a very variable behavior which could theoretically allow them to produce sequences which differ from the 10 previous ones. However, they seem to have difficulties in understanding the precise contingencies of the task and/or to adopt a systematic procedure in varying their sequences.
2. As we had hypothesized, a variability training seems to facilitate the subjects' adaptation to new contingencies. However, this effect is found in adults only and it is so tenuous that it needs to be confirmed, with a greater number of subjects.

3. While the level of spontaneous variability does not seem to be influenced by the subjects' educational background, it seems to be tied to their capacity to master the task and to adjust to variability requirements. Here also, it is necessary to confirm these results with a greater number of subjects, by trying to dissociate the respective effects of the level of study and of the type of study.

As in experiment 1, no relation was found between the subjects' "mobility of thought" or their "field-dependence/independence" and their behaviors in the Visual Matrix task.

5.2. EXPERIMENT 3

5.2.1. AIMS OF EXPERIMENT 3

Results of experiment 2 have led us to carry out a similar experiment *with a larger number of subjects*. In this experiment, the level of school education, the type of school education and the socio-economical origin of the subjects have been taken into account.

As noted in chapter 2.5.2., another type of cognitive style, defined by Kaufmann (1979), has been considered.

So, the following questions were considered :

1. To what extent can subjects vary their behavior to adapt themselves to a situation that requires variability ?
2. Does variability training facilitate the subjects' adaptation in a situation in which only three sequences are reinforced ?
3. Are the subjects' behaviors different depending upon their level and their type of educational background on one hand, and their cognitive style "Assimilator - Explorer", on the other hand ?

5.2.2. METHOD

5.2.2.1. Subjects :

69 male subjects were chosen among the militiamen present in a training center of the Belgian Army (Centre d'instruction de SAIVE) on February 1, 1988. By applying to this population, we hoped to easily constitute a sample of subjects with constrasted types and levels of educational background. Their age were ranging from 18 to 27 years. They came from 3 squads, without any particular characteristics, and were selected on the basis of their availability.

The subjects were distributed into 2 categories as a function of their type of school education; into 3 categories as a function of their level of school education and into 3 categories as a function of their socio-economical origins.

1. Types of School Education - Variable 1 (VAR 1)

Our sample had to be roughly divided into 2 categories in order to obtain categories with sufficient and comparable effectives :

- Studies of Technical Type (T) :
  These subjects had received a training linked to the transformation of the matter or of materials. Their studies, according to their level, had generally given a great part to courses of Mathematics and of Physics:
  e.g. lathe operator, metal fitter, electrician, engineer, chemist, ...
- Studies of Non-Technical Type (Non-T) :
  These subjects were more oriented towards the social sphere and the services, or they were "people-oriented" :
  e.g. social worker, tourism worker, historian, lawyer, salesman, ...

2. Levels of School Education - Variable 2 (VAR 2)

The highest level of school education of each subject was taken into account.

- Lower Level (L) : Elementary School degree, Secondary School (inferior degree), ...
- Medium Level (M) : Secondary School (superior degree), ...
- Upper Level (U) : University Studies or equivalent studies.

VAR 2 / VAR 1	L	M	U	TOTAL
T	15	12	12	39
Non-T	6	8	16	30
TOTAL	21	20	28	69

$X^2 = 4.186$ df = 2 $P < 0.123$

Table 3.1 : Subjects' distribution as a function of type and level of school education

3. Socio- Economical Origin - Variable 3 (VAR 3)

The subjects' socio-economical origin was determined on the basis of the parents' profession and level of school education. Our categories were derived from those of LAUTREY (1980, p.124).

The parent with the highest level of school education or with the upper profession was taken into account .

- Category A : Subject's father or mother was an unskilled worker, a maintenance worker or had an Elementary School degree.
- Category B : Subject's father or mother was an office worker, a shopkeeper, or had a Secondary School degree.
- Category C : Subject's father or mother was an executive, professor, lawyer, doctor, etc or had University or equivalent education.

VAR 3 / VAR 1	CAT. A	CAT. B	CAT. C.	TOTAL
T	20	14	5	38
Non-T	2	17	11	30
TOTAL	22	31	16	69

$X^2 = 18{,}514$ df = 2 $P < 0.000$

Table 3.2. : subjects' distribution as a function of level of school education and of socio- economical origin.

VAR 3 / VAR 2	CAT. A	CAT. B	CAT. C	TOTAL
L	11	9	1	21
M	7	11	2	20
U	4	11	13	28
TOTAL	22	31	16	69

$X^2 = 17.974$ df = 2 $P < 0.001$

Table 3.3. : subjects' distribution as a function of level of school education and of socio-economical origin.

While the variables type and level of school education are presumably independant, they are both linked to the variable origins.

Subjects with the lowest socio-economical origin (cat. A) had nearly always chosen studies of technical type and, in half the cases, of low level. Subjects of middle origin (cat. B) were distributed in a similar manner among all the categories. Proportionally more subjects whose origin belong to the upper category (cat. C) are found in the non-technical type of school education. The great majority of them had followed university or equivalent studies.

These facts must be kept in mind in the analysis of subjects' results as a function of their type and of their level of school education, these variables (particularly for the extreme categories of the variable 3) being, at least in part, undissociable of the subjects' socio- economical origin.

5.2.2.2. Materials and Procedures

- Visual Matrix Task :
The same matrix types than in experiment 2 were used : the normal matrix (N), the normal matrixes with differential reinforcement (D and D_{10}), and the matrix with prescribed sequences (C).

Subjects were divided into 2 experimental groups matched as far as possible, for type and level of school education and they were individually submitted to 4 sessions of 50 trials each, in a room of their barracks. Each militiaman was seen only one time because of their hourly constraints.

		NNNC	$NDD_{10}C$	TOTAL
1. TYPES	T	21	18	39
	Non-T	15	15	30
2. LEVELS	L	10	11	21
	M	13	7	20
	U	13	15	28
3. ORIGINS	A	9	13	22
	B	19	12	31
	C	8	8	16
	TOTAL	36	33	69

Table 3.4. : Subjects' distribution as a function of type and level of school education and of socio-economical origin, in each experimental group.

- Task of Kaufmann: "Assimilator-Explorer" cognitive style

5.2.3. RESULTS

5.2.3.1. Visual Matrix Task :

Means and standard deviations of each index, for each experimental group and for each type and level of study, can be found in Appendix 3 (Tables 3.1 to 3.10, pp 98-107).

5.2.3.1.1. Performance and variability in N global and in each session of each experimental group, as a function of socio-professionnal variables :

For each index, Three-way ANOVA (type, level, origin) have been performed for N in first session for the global population (N global) and for each session of each experimental group, in order to get a general view of the influence of each socio-professional variable and of their interactions.

Only the comparison of subjects as a function of their type of studies (VAR 1) has a significant effect for all relevant indices in N global, and for some indices in several sessions of the experimental groups.

The level of studies (VAR 2) rarely shows a significant effect (only in the last session of the experimental group N D D_{10} C) and the origins (VAR 3) has no signifiant effect. No significant interaction effect is observed between the 3 variables.

Two-way ANOVA (type x level of school education) performed for N global and for each session of each experimental group, give similar results (see Tables 3.11 - 3.12 in Appendix 3 pp 108-109)

It has been decided to leave out variable 3 in the analysis of results. But it must not be forgotten that this variable is linked to the other two, as noticed in the description of the population. We have to take into account that, for the variable 1, nearly all the subjects with the lowest origins (CAT A) have chosen studies of technical type (T) and that they represent half the subjects in the category T. For variable 2, we must retain that the great majority of the subjects with the highest origins also have the highest level of school education and that half of the subjects with the lowest origins, also have the lowest level of school education.

- Performance and variability as a function of TYPE of school education:

Student T-tests for independent samples were used to compare the values of each index, as a function of both types of school education, for N global and for the same session of the same experimental group (see Tables 3.13-3.14 in Appendix 3 pp 110-111)

- N global :

Performance :

For all the population in N in the first session, the performance of subjects with non-technical school education is significantly higher than the performance of subjects with technical school education (respectively, % CS : 95.20 % > 89.05 %).

Variability :

All the indices assessing the sequences variability indicate that subjects with technical training are significantly more variable than those with non-technical training. This higher spontaneous variability among the population T is found for correct sequences as for incorrect sequences (respectively, % DS : (Non-T) 72 % > (T) 56,72 % ; NCS : 4.80 < 6.56; NIS : 2.27 < 3.33 ; U (S) : 1.33 < 2.07 ; U (CS) : 1.02 < 1.59; U(IS) : 0.88 < 1.45) (with ">" = "superior to" and "<" = "inferior to").

It is important to note that these differences as a function of type of study disappear for the subjects with an upper level of study

- Experimental group NNNC :

For each index, mean values as a function of type of school education and of session, are showed in figure 3.1. (p. 188).

Performance :

The performance of the population Non-T is at once very high. It always stays higher (significantly for the sessions 1 and 2) than the performance of the population T, which increases from the first to the third session.

In the last session, when the situation is complicated by the reinforcement of only 3 sequences that are rarely spontaneously emited, the performance (NSC x 2 : (Non-T) 42.80 % < (T) 53,52 %) decreases for both types of subjects, but especially for the population Non-T . If all the subjects need more trials to find out an appropriate sequence, subjects with non-technical training, particularly , produce more incorrect sequences.

Variability :

The level of variability (of correct and incorrect sequences) of the population T, that is significantly the highest level in first session, progressively gets close to the level of variability of the population Non-T. The variability of subjects with non - technical education stays nearly stable during the first 3 sessions (except a little decrease of the incorrect sequences variability from the first to the second session).

The dominant sequences (DS) distributions, as a function of session and of type of school education were examined (see table 3.5., p. 190) (X^2 reveals no significant difference as a function of type of school education). Corner sequences are chosen by the majority of subjects, followed by diagonal sequences.

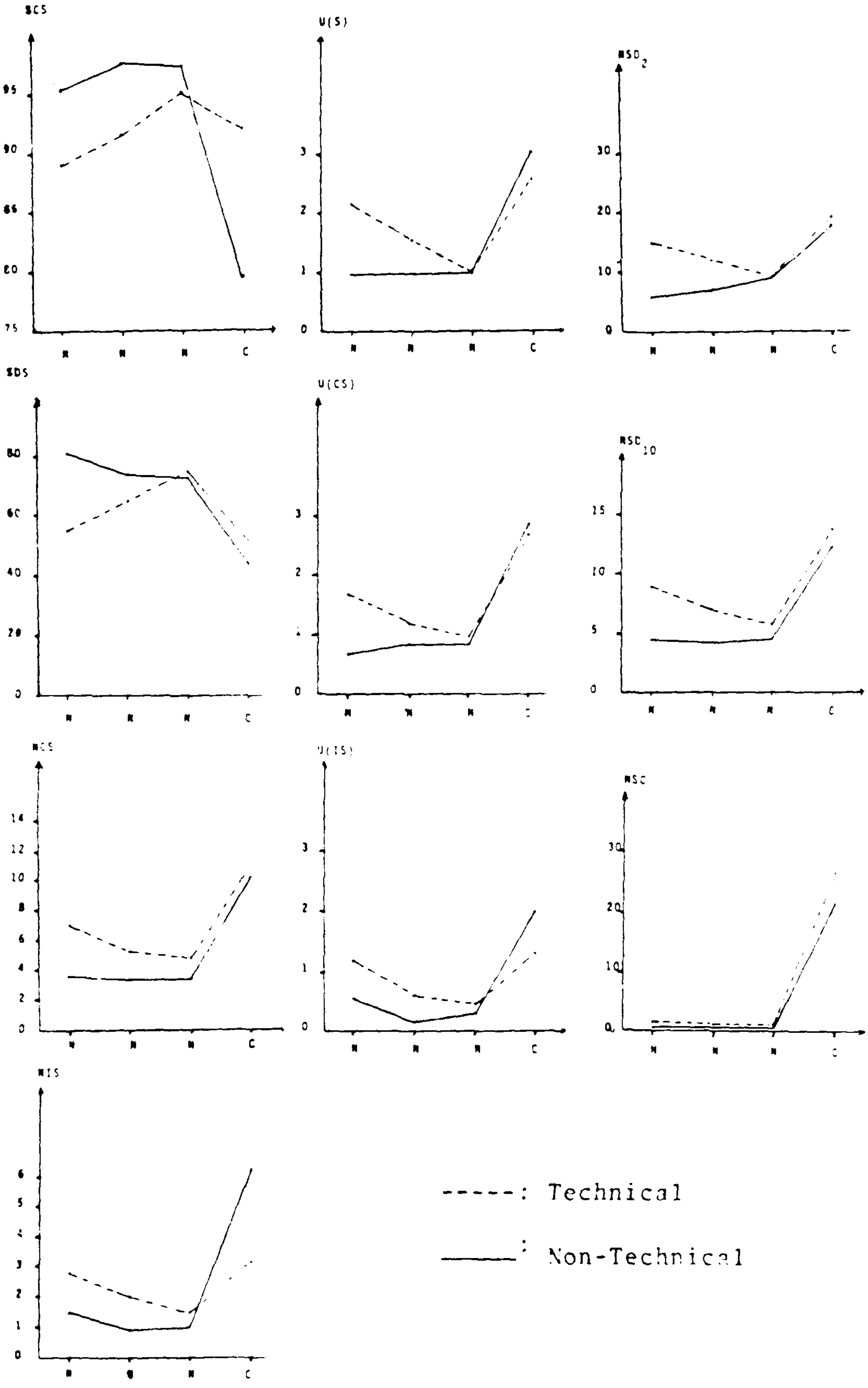

Fig. 3. 1. For each index, mean values as a function of session and for each type of school education, in the group NNNC

The matrix C produces an increase of the variability of correct sequences. The incorrect sequences variability also increases among subjects with technical education (reaching a level close to the one of the first session), but this increase is more pronounced among subjects with non-technical education.

Almost all the subjects adopt one of the reinforced sequences as DS, showing that, in general, they understand the rule of the task in C. This comprehension is preceded by an increase of their behavioral variability, when they are searching for a solution to the task. The subjects of the population T, who are at once less good performers but more variable in the first three sessions, prove to be a little more efficient in this search.

TYPE (VAR 1)	DS	N	N	N	C
TECHNICAL	1 CORNER	15 71.43	14 70	14 66.67	0
	2 DIAGONAL	2 9.52	5 25	5 23.81	1 4.76
	3 OTHER	3 14.29	1 5	1 4.76	0
	4 INCORRECT	0	0	0	0
	5 CONSTRAINT	1 4.76	0	1 4.76	20 95.24
NON - TECHNICAL	1 CORNER	9 60	9 64.29	11 73.33	1 6.67
	2 DIAGONAL	4 26.67	4 28.57	4 26.67	0
	3 OTHER	2 13.33	1 7.14	0	0
	4 INCORRECT	0	0	0	1 6.67
	5 CONSTRAINT	0	0	0	13 86.67

Table 3.5. : Absolute and relative frequencies of DS types as a function of session and of type of school education, in the group NNNC.

- Experimental group N D D_{10} C :

Figure 3.2. (p. 192) shows mean values for each index, as a function of type of school education and of session.

Performance :

The population Non-T perform slightly better in N in first session than population T, but this difference is less pronounced than in the group NNNC. For all subjects, the % CS increases from the first to the third session, despite the requirement of variability.

Like in experiment 2, we consider here the indices that correspond to the number of reinforcement in the matrixes D, D_{10} and C (Table 3.6.).

	N	D	D_{10}	C
T	87.33	68.00	47.78	56.88
Non - T	90.80	70.76	56.26	52.66

Table 3.6 : Percentages of reinforcement as a function of session and of type of school education, in the group NDD_{10} C.

In D and D_{10}, results are similar for the two populations : NSD_2 and NSD_{10} respectively increase, but the percentages of reinforcement are lower than those obtained in N in first session.

The same comments as in Experiment 2 can be made : subjects do not perfectly adapt themselves to the peculiar variability requirements, even if their results show that they perceive a modification of the contingencies between the second and the third session.

As expected, NSC increases in the fourth session. Although the % CS remain very high, the percentage of reinforcement (only a bit higher than 50 %) let suppose that many trials are necessary to grasp the rule in C.

Variability :

The significant differences of variability that have been observed betweenthe two populations types, in the first session of the group NNNC, do not appear here. This can probably be attributed to a sample effect : in the group $NDD_{10}C$, subjects with non-technical training show at one poorer performance and they are more variable than in the other experimental group. But, results concerning differences between both types of subjects in NNNC must be considered with some caution, as emphasized above.

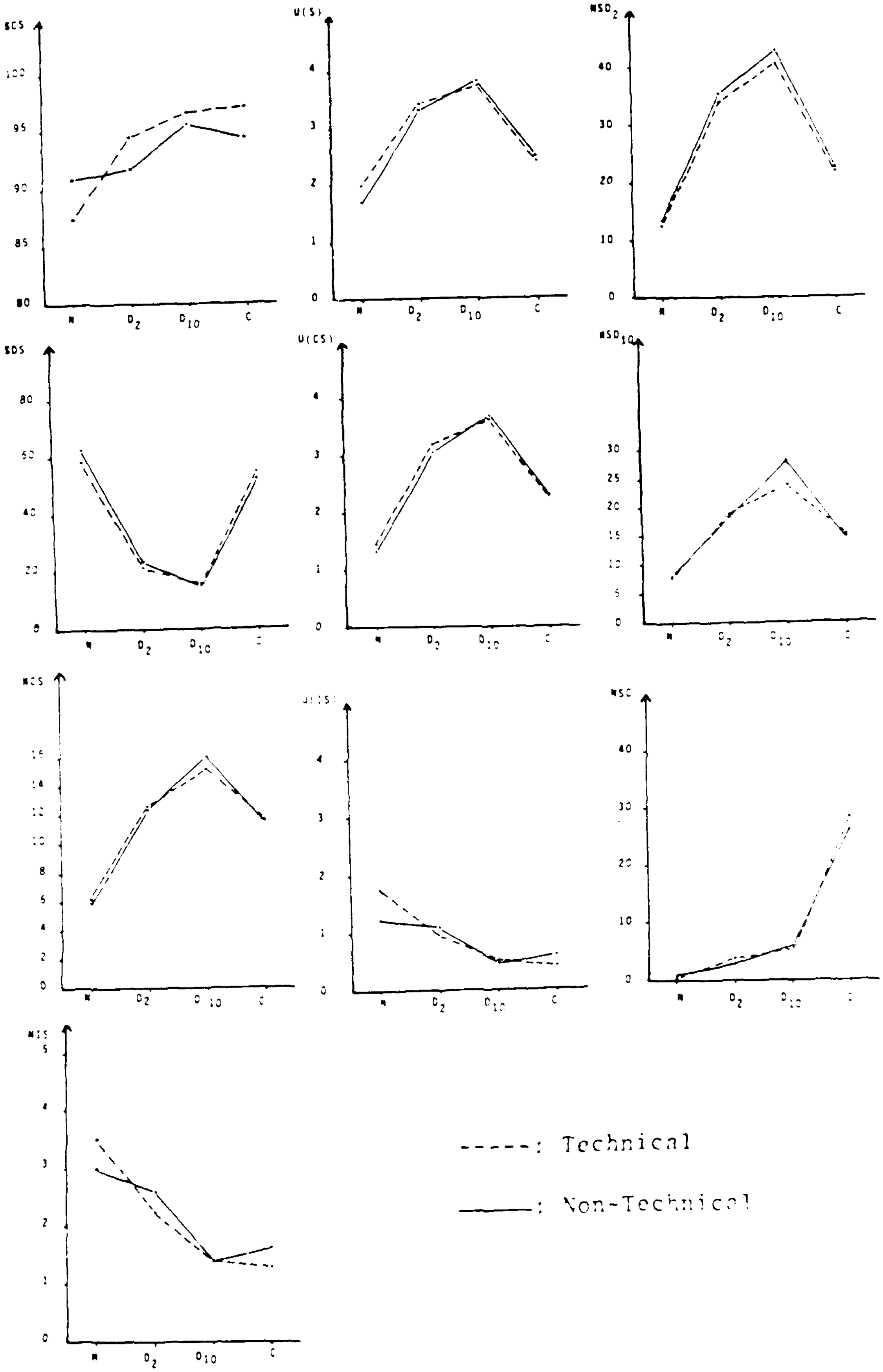

Fig. 3. 2. For each index, mean values as a function of session and for each type of school education, in the group $NDD_{10}C$

The matrixes D and D_{10} produce, as usual, an increase in general variability, which can be explained by the increase in variability of correct sequences. More than 75 % of the possible correct sequences are employed in D_{10}. The incorrect sequences variability progressively decreases during the first 3 sessions.

In D and D_{10}, the variability of both populations evolves in a similar way. Distributions of D.S. types (see Table 3.7. p. 194) are nearly identical in N and in D. The majority of subjects choose corner sequences as DS. The matrix D_{10} entails a modification of these distributions : subjects prefer here "other" DS. This contributes to the greater variability obtained with this matrix.

The matrix C leads to a reduction of the general variability, in comparison with the variability in D and especially in D_{10}, but the level of the correct sequences variability remains higher than in N in first session. It surely reflects the period of adaptation (search for a solution) to the task in C.

Distributions of D.S. types show that nearly all the subjects of both populations take one of the three reinforced sequences as D.S. It confirms that the great majority of them succeed in mastering the task (more or less rapidly).

TYPE (VAR 1)	DS	N	N	N	C
TECHNICAL	1 CORNER	9 50	8 44.44	6 33.33	0
	2 DIAGONAL	5 27.78	5 27.78	3 16.67	1 5.56
	3 OTHER	4 22.22	5 27.78	8 44.44	1 5.56
	4 INCORRECT	0	0	0	0
	5 CONSTRAINT	0	0	1 5.56	16 88.89
NON - TECHNICAL	1 CORNER	9 60	9 60	4 26.67	0
	2 DIAGONAL	2 13.33	3 20	3 20	1 6.67
	3 OTHER	3 20	3 20	8 53.33	1 6.67
	4 INCORRECT	0	0	0	0
	5 CONSTRAINT	1 6.67	0	0	13 86.67

Table 3.7. · Absolute and relative frequencies of DS types as a function of session and of type of school education, in the group $NDD_{10}C$.

- Performance and variability as a function of LEVEL of school education :

Means and standard deviations for each index in N-global and in each session of each experimental group, as a function of level of school education can be found in Appendix 3 (Tables 3.5 to 3.10, pp102-107).

One-Way ANOVA (Level) and Newman-Keuls tests (NK) were used to compare the values of each index as a function of the level of school education, in N global and in each session of each experimental group.

The differences as a function of level of school education are significant only in the fourth session of the experimental group $NDD_{10}C$ for the following indices :

- % DS : $F(2,32) = 3.13$, $p = .05$; NK : NS
- U(CS) : $F(2,32) = 3.80$, $p = .03$; NK : M significantly superior to U with $p < .05$
- NSD_2 : $F(2,32) = 4.67$, $p = .01$; NK : M > U
- NSD_{10} : $F(2,32) = 3.23$, $p = .05$; NK : M > U

In the fourth session of this experimental group, subjects with medium level of study receive less reinforcements than the others (particularly in comparison with subjects of the category U) and they are the most variable with regards to correct sequences. However, these differences observed in C as a function of level of study, cannot be put in relation with any particular behavior during the previous sessions (in N, D and D_{10}, there is no difference as a function of level of study).

5.2.3.1.2. Comparison of the two experimental groups, in each type of school education:

Only results as a function of type of school education are taken here into account, since this variable is the only one which allow to significantly differentiate the subjects.

- Comparison of behaviors in N in first session :

For each index, Two-Way ANOVA (experimental group X type of school education) in the first session (see Table 3.15 in Appendix 3, p 112) were completed by students T-tests (experimental group) in first session, for the global population (see Table 3.16 in Appendix 3, p113).

Two-way ANOVA reveals significant effects of the factor Group for the indices relative to the variability of incorrect sequences (NIS and U (IS)). Significant effects of interaction between the two variables are

obtained for the indices relative to the general variability (% DS and U (S)) and to the variability of correct sequences (NCS and U (CS)). It means that the 2 experimental groups may not be considered as equivalent (sampling effects).

All the subjects in the group NNNC perform better. They produce therefore less different incorrect sequences than subjects in the group N D D_{10} C (as confirmed by the student T-Test). Both population types are at once more differentiated in the group NNNC, principally because the most stereotyped subjects of the population Non-T belong to this experimental group. On the contrary, results of the group $NDD_{10}C$ do not enable to differenciate the two types of populations.

- Comparison of behaviors in N and D, in second session :

Figure 3.3. (p. 197) presents, for each index, mean values as a function of type of school education and of matrix type (N and D), in the second session.

Two-way ANOVA (Matrix X Type) does not reveal any effect due to type of school education. (see Table 3.17 Appendix 3 p 114).

As in the experiment 2, the factor Matrix has significant effects on indices relative to the general variability, to the variability of correct sequences and on NSD_2. Significant effects obtained for the variability of incorrect sequences must be put in relation with differences pre-existing between the 2 experimental groups. (The incorrect sequences variability in first session is more important in the group $NDD_{10}C$ than in the other group (sampling effect). In second session, it stays higher in the group $NDD_{10}C$ than in the other group. So, in second session, the difference between the 2 experimental groups with regard to the incorrect sequences variability cannot be attributed only to the factor Matrix in itself).

The two types of matrix within each population (T and Non-T) have also been compared (student T - Tests (Matrix) : see Table 3.18 Appendix 3 p 115).

Results show that all the subjects are able to adopt more variable behaviors when it is required, independently of their type of school education.

Distributions of D.S. types do not differ as a function of Matrix type (Table 3.5., p. 190 and Table 3.7., p. 194).

- Effects of pre-training on the behavior in C (fourth session) :

Figure 3.4. (p. 198) presents, for each index, mean values as a function of type of school education and of pretraining type, in C (fourth session).

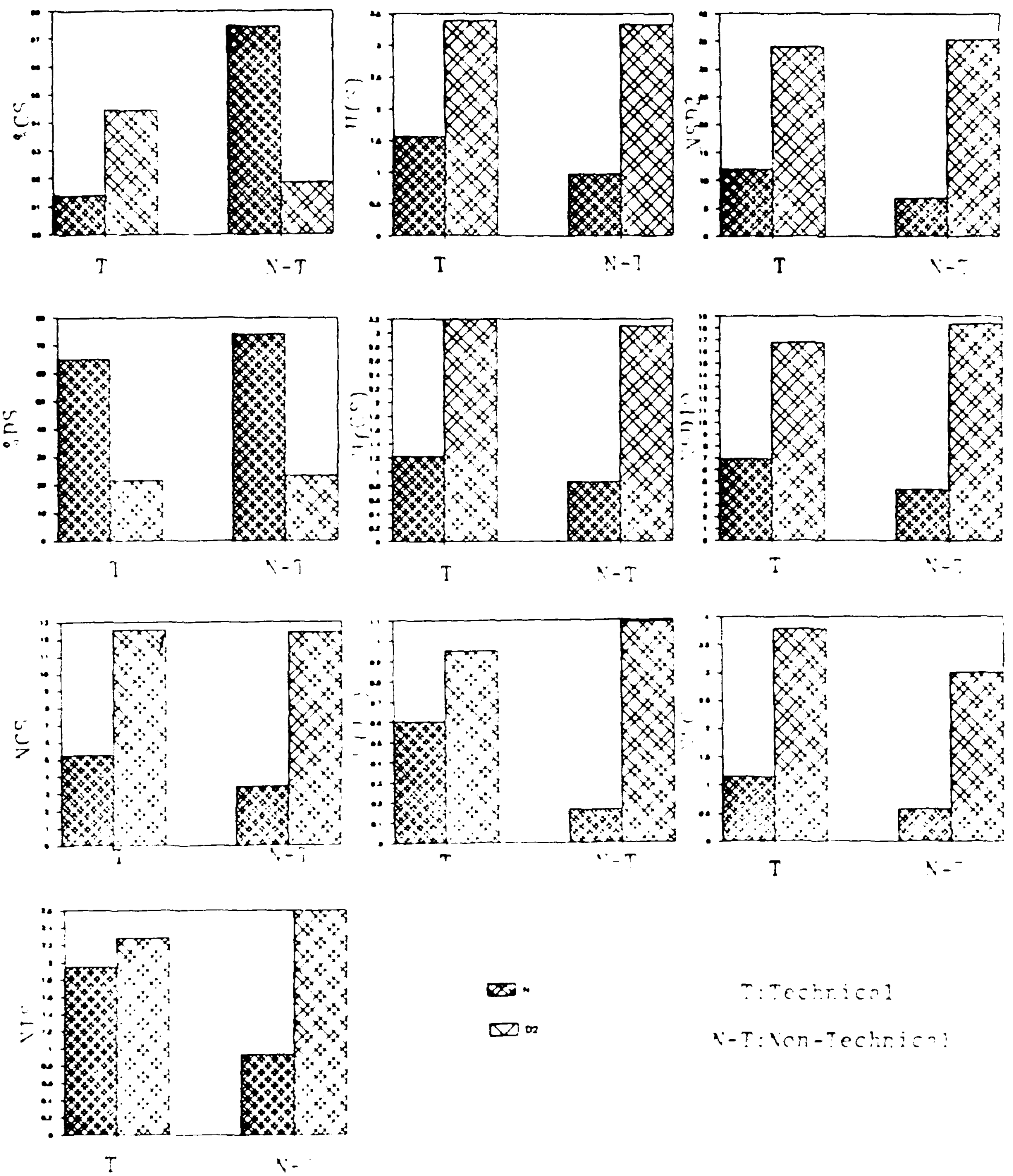

Fig. 3. 3. For each index, mean values as a function of type of school education and of matrix type (N and D), in the second session

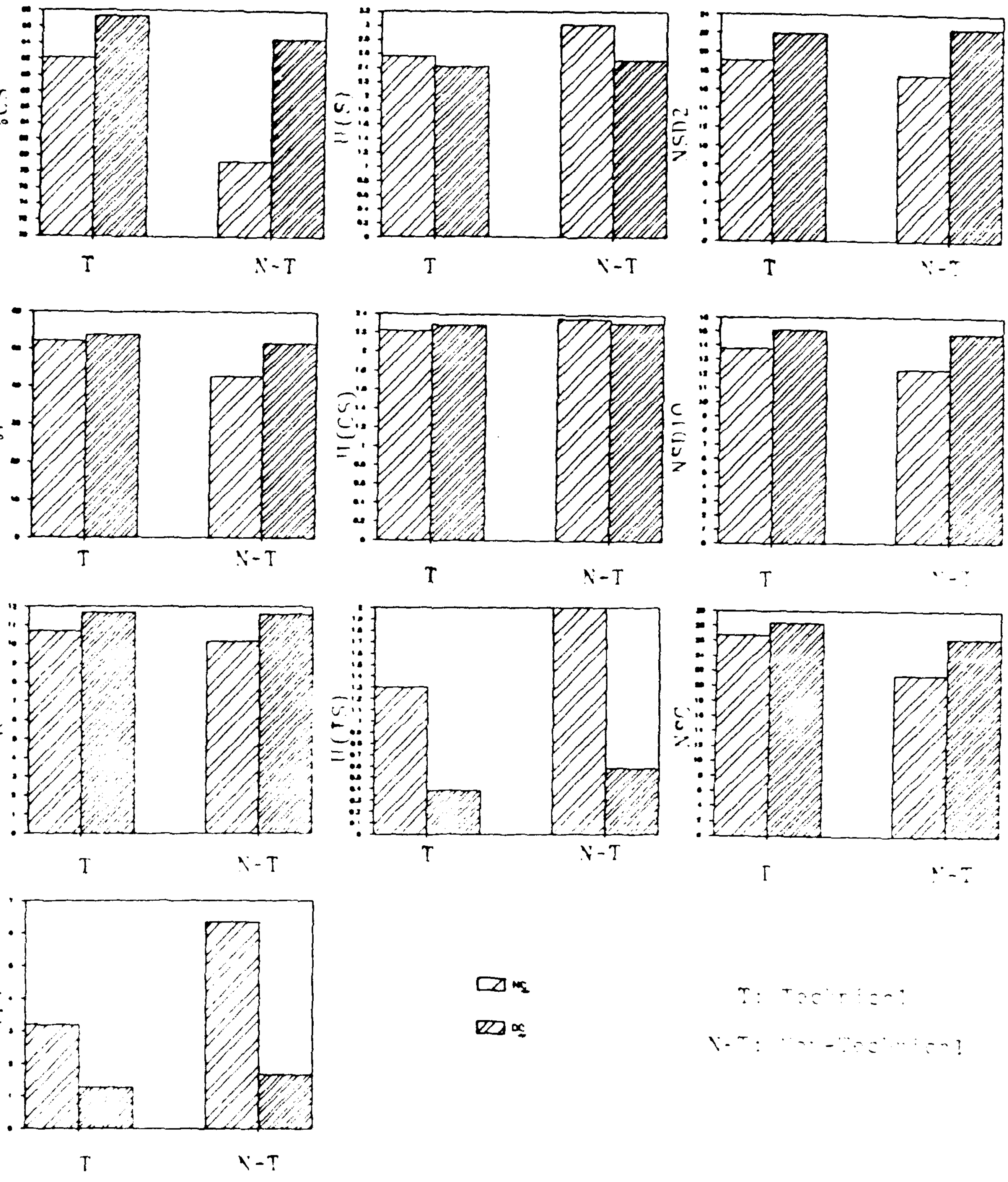

Fig. 3. 4. For each index, mean values as a function of type of school education and of pre-training type, in C (fourth session)

Two-way ANOVA (Pre-training X Type of school education) reveals significant effects of both factors on the % CS and on NIS, and of the factor Pre-Training on U(IS) (see Table 3.19 in Appendix 3 p116).

In both experimental groups, the population T produces less incorrect sequences and has a better performance than the population Non-T (in NNNC: (T) 53.52 % > (Non-T) 42.80 %; in $NDD_{10}C$: (T) 56.88 % > (Non-T) 52.66 %).

As in the first session, the difference between the 2 types of population is less pronounced in the experimental group $NDD_{10}C$.

The comparison of subjects as a function of their pre-training within each population (student T-test (pre-training) : see table 3.20 in Appendix 3, p 117), shows that the variability training results in a slightly better performance in C (subjects produce less incorrect sequences). However, this effect is not significant.

In fact, the examination of the 50 sequences emitted by some subjects of the group $NDD_{10}C$ in the fourth session, let think that the variability training can have a facilitating or a disturbing effect on the performance in C, depending on subjects. Some subjects who have received this training have not directly perceived the modification of contingencies and have continued to vary as before, even when they had emitted one of the three appropriate sequences. Other subjects tend to repeat the sequence which has been reinforced, maybe to test if they are or not submitted to the same contingencies. On the other hand, it seems that subjects of the group NNNC need a few more trials to find one of the appropriate sequences than the subjects of the group $NDD_{10}C$ (subjects of the group NNNC emit one of the three appropriate sequences for the first time at the trial number 20; subjects of the group $NDD_{10}C$ do it at the trial number 12).

5.2.3.1.3. Relation between spontaneous behaviors and behaviors observed in latter sessions

Given the importance of the inter-individual variations of behavior, an other type of analysis has been used. In order to determine the specific aspects of the spontaneous behavior that are related to behaviors observed in later sessions, correlations were computed between the indices of performance and of variability in first sesssion (% CS and U (CS)) and the indices of performance and variability in D, D_{10} and C (NSD_2, NSD_{10}, NSC and U (CS)).

The following points can be made:

- the % CS in first session is significantly correlated with the % CS

in D (ρ = .50, p = .002) and with the % CS in D_{10} (ρ = .49, p = .003) but not with the % CS in C (ρ = .29, p = .29).

- the % CS is first session is significantly correlated with NSD_2 in D (ρ = .38, p = .04) and with NSD_{10} in D_{10} (ρ = .41, p = .01) but is not related with the NSC in C (ρ = .08, p = .63).
- the % CS in first session is significantly correlated with U (CS) in D_{10} (ρ = .51, p = .002) but not with U (CS) in D (ρ = .2, p = .26) or in C (ρ = .07, p = .66).
- U (CS) in first session is not correlated with U (CS) in D, D_{10} or C.

These results clearly show that it is the capacity to master the task - and not the level of spontaneous variability - that is tied to the capacity to adequately adapt oneself to the precise requirements of variability.
On the other hand, the subjects' behaviors in C cannot be put in relation with their previous behaviors (resülts are similar for the experimental group <u>N</u>NN<u>C</u>).

These results are akin with one of the conclusions of experiment 1 : the potentialities for variation (and thus the capacity of adaptation) *depend upon the mastery* of a set of basic behavioral units (notably, in this case, the capacity to master the functioning rules of the matrix).

5.2.3.2. <u>Task of Kaufmann</u>

5.2.3.2.1. <u>Description of results</u> :

If a subject used the standard principle throughout the 6 test problems, he was placed in the <u>Assimilator</u> category. If he employed one or more deviant solution-alternatives, he was categorized as <u>Explorer</u>.

According to the definition of this cogintive style, we should expect a significantly higher number of Explorers who find the solution to the problem 7 (which cannot be solved by the standard principle), as compared to the Assimilators.

Indeed, 14 subjects (46.67 %) on the 30 subjects in the Assimilator category were not able to solve this simple problem within a 3-minute period. Among the 38 subjects in the Explorer category, only one subject failed to solve problem 7. As showed in the Table 3.8., the relation between the subjects' cognitive style and the success in the last problem, is confirmed independently of the number of successful test-problems (X^2 = 19.127, df = 3, p = 0.000). These results are similar to those obtained by Kaufmann.

SUCCESS TO THE TEST-PROBLEMS AND TO THE PROBLEM 7	COGNITIVE STYLE Assimilator	Explorer	Total
Subjects who solve the 6 test-problems and the last problem	11 36.67	27 71.05	38
Subjects who solve the 6 test-problems but not the last problem	9 30.00	1 2.63	10
Subjects who do not solve the totality of the 6 test-problems but success the last problem	5 16.67	10 26.32	15
Subjects who solve neither the totality of the 6 test-problems nor the last problem	5 16.67	0 0.00	5
Total	30	38	

Table 3.8. : Absolute and relative frequencies of subjects as a function of their success in the test-problems and in the last problem.

The results have been analysed with respect to level and type of school education. No difference was found as a function of the subjects' type of study. As shown, in table 3.9., the number of problems successfully solved is significantly related to the level of study (X^2 = 9.887, df = 4, p = 0.048).

NUMBER OF PROBLEMS SUCCESSFULLY SOLVED	LEVEL OF STUDY Low	Medium	Upper	Total
2 to 5	7 33.33	2 10.00	2 7.14	11
6	7 33.33	7 35.00	6 21.43	20
7	7 33.33	11 55.00	20 71.43	38
Total	21	20	28	

Table 3.9. : For each level of study, absolute and relative frequencies of subjects in each of 3 classes of performance (based on number of problems successfully solved at the Kaufmann's task).

There is a higher percentage of Assimilators (50 %) among subjects with a low level of study than among subjects with a medium or upper level of study (35 % and 39.29 %, respectively). However, the relation is not significant.

It is also among the subjects with a low level of study that the greatest number of subjects (45 %) who fail to solve the last problem is found (against 20 % of the subjects M and 7.14 % of the subjects U).

5.2.3.2.2. Relations between the subjects' cognitive style and performance and variability indices :

In each experimental group, subjects have been separated in two sub-groups as a function of their congitive style and the mean results of these two sub-groups for session 2, 3 and 4 of each experimental group have been computed (for the first session (N global), subjects of the two experimental groups were gathered).

Results can be found in Appendix 3, tables 3.21, 3.22 and 3.23, pp 118-120. (For each index, Student T-tests (cognitive style) were used in N global and in the sessions 2, 3 and 4 of each experimental group).

Only very slight differences between the 2 types of subjects were found : in N global and in the sessions 2 and 3 of the group NNNC, the Explorers tend to be a little more variable with regard to the correct sequences than the Assimilators To the contrary, the reverse tendency is observed with the matrixes which request variability (D and D_{10}). For these matrixes, the Explorers tend to be more variables in incorrect sequences (the differences are significant only in D_{10}, for the following indices : NIS : $t = -2.09$, $p \leq .05$; U(IS) : $t = -2.66$, $p \leq .05$). In the last session for both experimental groups (C), the behaviors of the 2 types of subjects are similar.

5.2.4. CONCLUSIONS OF EXPERIMENT 3

Globally, results of this experiment are similar to those of Experiment 2, with regard to adults' behaviors in each matrix type.

As usual in the normal situation (N), subjects have a good performance. It is in this situation that the variability of correct sequences is the lowest. However, subjects keep always a certain level of variability.

When the reinforcement contingencies demand it, subjects produce more variability and the level of variability that they reach with the matrix D_{10} is theoretically sufficient to allow them to meet these contingencies (they produce 75 % of the possible correct sequences). But like in Experiment 2, they have difficulties to adapt to this situation (they obtain a low percentage of reinforcement in D_{10}).

As in previous experiment, low performance is observed in matrix C. A variability training entails a slightly better performance when defined behaviors are required from the subjects (C). However, as noted before, the examination of the 50 sequences emitted by some subjects of the group $NDD_{10}C$ in the fourth session, let think that the variability

group $NDD_{10}C$ in the fourth session, let think that the variability training can have a facilitating or a disturbing effect on the performance in C, depending upon the subjects. For some subjects, a training in D, would facilitate the adaptation to the matrix C by increasing the probabilities to emit more rapidly one of the three appropriate sequences.

On an other side, some results clearly show that the capacity to master the task in the first session - and not the level of spontaneous variability - is tied to the capacity to efficiently adapt oneself to the precise requirements of variability.

This is akin with a hypothesis emitted in Experiment 1 : even within a population of adults, the potentialities for variation are dependent upon the mastery of a set of basic behavioral units. In the situation used, it refers to the capacity to master the functioning rules of the matrix.

While adults differ with regard to their performance and variability in the Visual Matrix Task, these inter-individual differences cannot be put in relation with the subjects' cognitive style "Assimilator-Explorer" (just like in the experiments 1 and 2, these differences could not be put in relation with the subjects' "mobility of thought" or their "field-dependence / independence" cognitive style).

The level of study does not seem to be tied to the performance or the variability observed in the Visual Matrix Task.

But, adaptation to the task in the first session seems to be tied to the type of study : in the first session, subjects who have followed a technical training perform poorer and are more variable (with regard to correct and incorrect sequences) than other subjects. With regard to the performance, the difference between the two types of subject disappears for subjects with an upper level of study.

In Experiment 2, subjects of population T performed poorer in N and in D than subjects of population G. *In this experiment, no significant* difference between the two types of subject was found in situations which request variability (in D_{10} only, subjects with a technical training tend to perform slightly poorer than the other ones). However, it must be recalled that it is precisely in the group $NDD_{10}C$ that the two types of subjects do not significantly differ with regard to their performance in the first session and, if we take into account the relation observed between the performance in the first session and the performances in D and D_{10}, this sample effect could and D_{10} in this experiment.

In the two experimental groups, subjects with a technical educational background, stay a bit more variable than the other subjects and they perform better in the last session. However, the differences are not significant.

CHAPTER 6

CONCLUSIONS

The results of experiments reported here suggest that our approach to behavioral variability bears upon dimensions of behavioral and cognitive processes that are not dealt with by other approaches to the study of intelligence, problem-solving, mobility of thought, fluidity and the like which, at first sight, might seem conceptually close to ours. No significant relation has been found between behavioral variability as assessed by our procedure and relevant measures derived from procedures developed in some of these other approaches. This does not mean that possible links between various approaches are to be discarded, but it is a strong argument to proceed further along the same lines. Data gathered so far are admittedly not sufficient to validate and qualify the general theory proposed in chapter 2.1. They are, however, sufficient to encourage further investigation within this framework.

Concerning behavioral variability, empirical results obtained with adults and adolescents support the conclusion that stereotypy is not the inevitable outcome of reinforcements even in situation, where variability is not required. Even though the contingent reinforcements produce some stereotypy, the subjects always keep a certain level of variability. This is comparable to this fraction of exploratory behavior preserved in normal rats after they reach an asymptotic level of running time, upon which they are by no means unable to improve. Moreover, subjects are able to modify their behavior to adapt themselves to modifications of the environment.

These points converge with the conclusions reached by Wong and Peacock (1986) when they write - in opposition to Schwartz - " ... behavioral units may not be rigid structures that are emitted in an automatic and invariant manner regardless of changes in reinforcement contingencies. In other words, stereotypy does not become counterproductive when the contingency is changed" (p. 157).

Some of our findings seem to support the hypothesis of the differential reinforcement of efficiency : the analysis of distributions of dominant sequence types as a function of matrix type shows that, when no coherent landmark is available, the great majority of individuals prefer diagonal dominant sequence. This motor strategy is, in fact, the easiest way to solve the problem. So, a great proportion of individuals select as D.S. only the sequences that maximize payoff even when other sequences have been reinforced.

Results also show that variability can be induced, or reduced, or increased, by changing the outcomes for a subject of his exhibiting variability and that a pretraining in variability leads the subjects to search for the solution of a new problem-situation, in an adequate way.

To sum up, these empirical results show that behavioral variability is a property of behavior that can be modulated by various

external factors, and that it is, indeed, amenable to the control by its consequences.

Data obtained with 5-6 y.o. and 9-10 y.o. allow us to qualify and complete these conclusions. Parallel to the improvement of the performance and to the increase of variability with age, the capacity to adopt adapted behaviors (more or less variable but efficient) to the present environment also increases as a function of age.

These results concord with those of El Hamadi (1982) and Hanlon (1960). Our findings can also be compared with those of Botson and Deliège (1976) who have shown that the capacity to switch from one solution to another in dealing with the same problem situations - of a familiar type in Piaget's procedures - increases as a function of age.

This allows to reject the idea that creative behavior is only a product of some inborn endowment.

The improvement with age of the capacity to master the functioning rules in the matrix task and of the capacity to adopt a more variable behavior, is akin with the hypothesis that the capacity of adaptation (and of learning) is a function of the potentialities for variation. These ones being themselves dependent on the mastery of a set of basic behavioral units.

Supplementary results, obtained with adults, concord also with this hypothesis. They clearly show that the capacity to master the task in first session is predictive of the capacity to efficiently adapt oneself to the precise requirements of variability.

It must be noted that, whatever age group is considered, the subjects' way to react to the initial conditions to which they have been exposed is itself much variable from one individual to another. Interindividual differences seem to concur with intraindividual variability to maximize the range of variations as expressed in a given population.

Though experimenters are usually reluctant to venturing in applications when empirical data are still scarce and obviously demand extensions and replication, a few, admittedly speculative remarks are in point as to practical applications. They are, after all, much less speculative than popularized myths of inborn creativity and of the deleterious action of any educational intervention on the creative potential of humans.

It seems to us counterlogical to think of variability in terms of traits or styles or types. If anything, it is a functional property of cognitive and behavioral processes. As such, it can be influenced by a number of perfectly identifiable variables, and, especially important, it can be increased.

If the role of variability is recognized as the common factor at work from simple motor learning to problem solving and to the

production of novel behavior, be it in unexpected life situations or in artistic creation, there is no need to oppose the realm of routine, automated, narrowly logical behavior to the realm of spontaneous, imaginative, creative behavior; the domain of rationality and teachability and the domain of unteachable, supposedly creative, irrationality. That man will cope with change, as he will be confronted to it, who will preserve a range of variation, upon accumulated highly trained skills. That man will produce novel pieces of art or science or writing who will keep on exploring potentialities with a background of expertise.

In the applied field of education, as noted by Richelle (1986, p. 13) : "Looking at learning / teaching in that way of course changes something important in a traditional approach to school education (or training). Teaching should provide numerous opportunities for variation. Teaching basic knowledge that is needed to build upon, especially in science, should be closely linked with training in variability ..."

The role of variability in solving problems under stress is plousibly no less important. Maximizing potentialities to adjust in stress situations could be, essentially, a matter of keeping a range of variations in spite of the restricting effect of emotion. Though, in the present report, the relevance of the concept of variability has been considered mainly in relation with learning, problem-solving and creativity - or what could be labelled cognitive functions - , it is suggested that it also offers interesting theoretical prospects in bringing together again emotion and cognition. The integration of which has been overlooked by contemporary exclusive emphasis on cognitive functions.

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Appendixes 1, 2 and 3

by

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APPENDIXES

APPENDIX 1

- List of tables

- Tables 1.1 to 1.62

LIST OF TABLES

1 **SCIENTIFIC**	BIOLOGY COMPUTER SCIENCE ECONOMICS ENGINEER GEOGRAPHY MEDECINE PHARMACOLOGY VETERINARY SURGEON PHYSIOTHERAPY
2 **NEUTRAL**	BUSINESS ADMINISTRATION PSYCHOLOGY UNSPECIFIED
3 **LITERARY**	JOURNALISM LANGUAGES LAW LITERARY PHILOSOPHY HISTORY

<u>TABLE 1.1.</u> : **Detailed list of the study types**

MEANS - % CORRECT SEQUENCES (%CS)						
	N	N	N	N	R	N
5-6 Y.O.	74.53	81.73	87.20	75.22	58.66	75.55
9-10 Y.O.	87.20	94.26	92.90	93.88	67.55	93.77
14-15 Y.O.	93.00	95.29	96.23	93.70	80.11	97.40
ADULTES	94.20	93.33	91.52	91.60	80.50	97.50
	N	D	N	D	R	N
5-6 Y.O.	81.50	86.87	89.62	76.92	73.69	88.15
9-10 Y.O.	88	91.15	95.75	89	61.41	92.82
14-15 Y.O.	94.90	96.75	99.05	92.50	86.28	97.42
ADULTES	91.70	96.84	96.10	91.80	82.20	94.10
	R	D	N			
5-6 Y.O.	78.30	71.17	78.82			
9-10 Y.O.	51.50	82.82	94.58			
14-15 Y.O.	65.60	87.52	92.87			
ADULTES	75.70	93.26	97.17			

STANDARD DEVIATIONS - % CORRECT SEQUENCES (%CS)						
	N	N	N	N	R	N
5-6 Y.O.	26.12	24.34	10.97	22.10	29.16	29.26
9-10 Y.O.	17.91	19.27	17.13	5.70	19.44	13.73
14-15 Y.O.	6.40	5.47	4.40	9.30	19.76	2.68
ADULTES	4.70	8.61	21.19	11.00	20.04	3.66
	N	D	N	D	R	N
5-6 Y.O.	19.10	9.90	14.08	19.90	20.04	10.08
9-10 Y.O.	9.10	5.89	3.76	7.40	18.62	7.71
14-15 Y.O.	4.20	2.76	1.68	6.60	19.38	3.64
ADULTES	8.90	3.69	5.21	13.7[illegible]	10.23	20.79
	R	D	N			
5-6 Y.O.	20.60	24.76	18.64			
9-10 Y.O.	18.10	13.49	4.62			
14-15 Y.O.	15.50	14.16	11.03			
ADULTES	17.70	4.72	3.60			

<u>TABLE 1.2.</u> : **% CS : means and standard deviations in each experimental group and in each age group**

MEANS -				% DOMINANT SEQUENCES (%DS)		
	N	**N**	**N**	**N**	**R**	**N**
5-6 Y.O.	57.06	67.46	67.86	54.77	44.11	55.88
9-10 Y.O.	57.70	64.80	66.80	59.88	45.44	73.77
14-15 Y.O.	52.70	54.58	54.70	55.80	59.20	74.80
ADULTES	61.23	62.47	63.71	57.30	51.60	61.10
	N	**D**	**N**	**D**	**R**	**N**
5-6 Y.O.	70.12	49.50	70.50	36.92	50.46	68.92
9-10 Y.O.	61.15	33.36	55.57	23.88	36.94	38.94
14-15 Y.O.	52	20.52	39.47	20.57	62.66	53.04
ADULTES	54	21.80	43.20	20.70	61.80	49.10
	R	**D**	**N**			
5-6 Y.O.	49.52	40.94	61.52			
9-10 Y.O.	27.41	31.17	48.82			
14-15 Y.O.	46	24.47	45.52			
ADULTES	57.78	28.52	44.73			

STANDARD DEVIATIONS -				% DOMINANT SEQUENCES (%DS)		
	N	**N**	**N**	**N**	**R**	**N**
5-6 Y.O.	22.70	21.13	25.47	23.00	23.26	23.21
9-10 Y.O.	24.20	27.13	27.83	23.00	24.29	26.11
14-15 Y.O.	27.90	25.93	26.84	20.70	24.98	21.89
ADULTES	26.10	27.47	28.49	24.00	24.00	33.10
	N	**D**	**N**	**D**	**R**	**N**
5-6 Y.O.	24.40	16.00	28.83	18.50	20.88	16.07
9-10 Y.O.	22.30	12.77	27.87	11.40	21.17	23.14
14-15 Y.O.	25.50	6.38	29.86	7.20	21.85	30.54
ADULTES	26.40	11.19	33.29	5.90	18.72	29.11
	R	**D**	**N**			
5-6 Y.O.	18.70	18.33	24.30			
9-10 Y.O.	13.30	17.90	25.94			
14-15 Y.O.	21.80	9.14	28.50			
ADULTES	20.30	10.82	26.71			

<u>TABLE 1.3.</u> : % DS : means and standard deviations in each experimental group and in each age group

MEANS - NB. CORRECT DIFFERENT SEQUENCES (NCS)						
	N	N	N	N	R	N
5-6 Y.O.	5.40	3.93	3.86	5.11	5.72	4.50
9-10 Y.O.	6.70	4.20	4.60	5.77	6.94	4.83
14-15 Y.O.	6.40	5.76	5.94	6.20	5.35	3.25
ADULTES	6.70	6.00	5.09	6.05	6.80	6.45
	N	D	N	D	R	N
5-6 Y.O.	3.43	5.25	4.06	6.61	5.76	4.46
9-10 Y.O.	5.26	8.57	6.89	11.41	7.70	9.70
14-15 Y.O.	8.10	13.63	9.73	13.33	4.47	7.66
ADULTES	7.20	13.55	10.15	13.05	4.60	8
	R	D	N			
5-6 Y.O.	5.41	5.82	4.52			
9-10 Y.O.	8.23	9.58	7.76			
14-15 Y.O.	6.47	10.47	7.70			
ADULTES	5.15	8.89	7.05			

STANDARD DEVIATIONS - NB. CORRECT DIFFERENT SEQUENCES (NCS)						
	N	N	N	N	R	N
5-6 Y.O.	3.10	2.57	2.77	3.10	3.44	2.43
9-10 Y.O.	3.90	3.20	3.73	3.20	2.87	3.97
14-15 Y.O.	3.90	3.45	3.05	4.40	2.58	2.22
ADULTES	4.40	4.40	4.01	3.80	3.95	5.48
	N	D	N	D	R	N
5-6 Y.O.	2.30	2.72	3.29	3.30	3.03	2.56
9-10 Y.O.	2.50	3.18	4.79	4.40	2.99	4.42
14-15 Y.O.	5.00	2.58	4.95	3.70	1.66	5.75
ADULTES	4.10	4.46	6.22	3.90	2.47	6.38
	R	D	N			
5-6 Y.O.	1.60	2.87	2.45			
9-10 Y.O.	2.50	4.31	5.43			
14-15 Y.O.	2.70	4.06	4.98			
ADULTES	2.50	4.17	4.37			

<u>TABLE 1.4.</u> : NCS : means and standard deviations in each experimental group and in each age group

MEANS - NB. INCORRECT DIFFERENT SEQUENCES (NIS)

	N	N	N	N	R	N
5-6 Y.O.	5.73	4.33	3.26	5.11	9.33	5.22
9-10 Y.O.	3.30	2.05	2.10	2.22	9.16	2.16
14-15 Y.O.	2.64	1.82	1.47	1.90	6.40	.95
ADULTES	2.23	2.00	1.61	2.40	5.70	1.05

	N	D	N	D	R	N
5-6 Y.O.	3.25	3.62	3.06	5.15	6.53	3.30
9-10 Y.O.	2.87	2.84	1.62	3.92	9.17	2.41
14-15 Y.O.	1.94	1.63	.47	2.61	3.71	1
ADULTES	2.40	1.40	1.36	2.90	6.40	1.30

	R	D	N
5-6 Y.O.	5.70	6.29	4.41
9-10 Y.O.	11.41	5.11	2.17
14-15 Y.O.	9.47	3.66	2.14
ADULTES	7.36	2.84	1.26

STANDARD DEVIATIONS- NB. INCORRECT DIFFERENT SEQUENCES (NIS)

	N	N	N	N	R	N
5-6 Y.O.	4.00	3.37	2.68	3.90	5.66	4.88
9-10 Y.O.	2.60	3.17	3.83	1.80	4.47	3.66
14-15 Y.O.	2.30	2.15	1.41	2.10	4.86	.94
ADULTES	1.80	1.73	1.62	1.70	4.37	1.50

	N	D	N	D	R	N
5-6 Y.O.	2.20	2.50	3.97	2.70	3.99	2.49
9-10 Y.O.	1.60	1.83	1.33	2.40	4.06	2.32
14-15 Y.O.	1.70	1.38	.84	2.10	3.50	1.37
ADULTES	2.10	1.63	1.26	3.50	3.01	3.09

	R	D	N
5-6 Y.O.	4.00	4.52	3.04
9-10 Y.O.	3.80	3.62	1.70
14-15 Y.O.	3.30	3.36	2.45
ADULTES	3.90	1.86	1.59

<u>TABLE 1.5.</u> : NIS : means and standard deviations in each experimental group and in each age group

MEANS - NB. SEQ. DIFF. 2 PREV. (NSD$_2$)

	N	N	N	N	R	N
5-6 Y.O.	12.40	9.13	10.20	12.94	12.55	10.77
9-10 Y.O.	16.20	11.93	11.30	16.27	14.16	10.22
14-15 Y.O.	18.30	19.70	20.41	16	11.45	9.55
ADULTES	15.30	14.09	13.23	13.50	14	17.60

	N	D	N	D	R	N
5-6 Y.O.	7.81	16	10.06	17.23	15	12
9-10 Y.O.	13.57	24.94	19.84	31	17.11	27
14-15 Y.O.	20.52	38.42	32.15	35.85	11.33	21.09
ADULTES	15.55	37.95	27.20	35.85	9.95	22.90

	R	D	N
5-6 Y.O.	14.64	15.64	11.05
9-10 Y.O.	15.58	25	20.17
14-15 Y.O.	11.11	29.66	25.70
ADULTES	9.36	31.15	26.89

STANDARD DEVIATIONS - NB. SEQ. DIFF. 2 PREV. (NSD$_2$)

	N	N	N	N	R	N
5-6 Y.O.	8.00	5.42	7.62	7.30	6.03	4.96
9-10 Y.O.	10.73	10.51	11.12	10.80	6.11	9.09
14-15 Y.O.	12.20	12.28	12.07	11.30	6.41	8.00
ADULTES	11.60	10.59	11.90	8.60	10.19	15.56

	N	D	N	D	R	N
5-6 Y.O.	6.90	7.06	8.91	7.60	5.78	5.65
9-10 Y.O.	7.70	7.21	14.39	9.90	5.61	12.96
14-15 Y.O.	12.00	5.84	15.51	7.20	9.05	15.15
ADULTES	9.80	7.22	17.02	6.50	7.30	16.03

	R	D	N
5-6 Y.O.	4.20	5.68	6.09
9-10 Y.O.	5.90	9.61	14.48
14-15 Y.O.	6.10	9.08	16.69
ADULTES	5.00	10.17	16.41

TABLE 1.6. : NSD$_2$: means and standard deviations in each experimental group and in each age group

MEANS - SEQUENCES UNCERTAINTY (U(S))

	N	N	N	N	R	N
5-6 Y.O.	2.14	1.57	1.45	2.14	2.72	1.97
9-10 Y.O.	2.01	1.44	1.40	1.75	2.87	1.25
14-15 Y.O.	2.01	1.81	1.78	1.83	2.10	.96
ADULTES	1.79	1.67	1.53	1.83	2.34	1.66

	N	D	N	D	R	N
5-6 Y.O.	1.35	2.10	1.36	2.69	2.44	1.54
9-10 Y.O.	1.82	2.74	1.90	3.34	3.23	2.68
14-15 Y.O.	2.10	3.45	2.53	3.52	1.66	1.94
ADULTES	2.03	3.38	2.48	3.48	1.96	2.12

	R	D	N
5-6 Y.O.	2.25	2.54	1.79
9-10 Y.O.	3.59	3.08	2.16
14-15 Y.O.	2.81	3.21	2.32
ADULTES	2.21	2.89	2.12

STANDARD DEVIATIONS - SEQUENCES UNCERTAINTY (U(S))

	N	N	N	N	R	N
5-6 Y.O.	1.10	.97	1.11	1.07	1.27	1.14
9-10 Y.O.	1.12	1.09	1.22	.94	1.12	1.24
14-15 Y.O.	1.22	1.08	.96	1.00	1.17	.76
ADULTES	1.16	1.16	1.13	1.04	1.11	1.36

	N	D	N	D	R	N
5-6 Y.O.	.96	.75	1.28	.90	1.03	.77
9-10 Y.O.	.96	.67	1.17	.77	.98	1.03
14-15 Y.O.	1.12	.30	1.28	.53	.88	1.39
ADULTES	1.17	.79	1.49	.53	.84	1.35

	R	D	N
5-6 Y.O.	.94	.98	1.05
9-10 Y.O.	.66	.94	1.22
14-15 Y.O.	.98	.57	1.88
ADULTES	.98	.70	1.06

TABLE 1.7. : U(S) : means and standard deviations in each experimental group and in each age group

MEANS -	CORRECT	SEQUENCES	UNCERTAINTY	(U(CS))		
	N	N	N	N	R	N
5-6 Y.O.	1.31	.95	.92	1.36	1.68	1.30
9-10 Y.O.	1.63	1.17	1.18	1.46	1.73	1.02
14-15 Y.O.	1.71	1.61	1.60	1.60	1.31	.82
ADULTES	1.52	1.42	1.23	1.51	1.62	1.54
	N	D	N	D	R	N
5-6 Y.O.	.75	1.55	.92	1.97	1.58	1
9-10 Y.O.	1.37	2.41	1.71	2.94	2.16	2.40
14-15 Y.O.	1.88	3.33	2.49	3.29	1.12	1.84
ADULTES	1.74	3.29	2.35	3.24	1.05	1.93
	R	D	N			
5-6 Y.O.	1.46	1.69	1.05			
9-10 Y.O.	2.27	2.52	1.94			
14-15 Y.O.	1.57	2.76	2.01			
ADULTES	1.20	2.59	1.99			

STANDARD DEVIATIONS-	CORRECT	SEQUENCES	UNCERTAINTY	(U(CS))		
	N	N	N	N	R	N
5-6 Y.O.	.97	.66	.83	.83	1.07	.79
9-10 Y.O.	1.06	.99	1.12	.93	.91	1.01
14-15 Y.O.	1.10	1.00	.93	.98	.86	.75
ADULTES	1.09	1.07	1.14	.93	1.01	1.34
	N	D	N	D	R	N
5-6 Y.O.	.78	.70	1.01	.97	.88	.59
9-10 Y.O.	.86	.67	1.15	.80	.82	1.04
14-15 Y.O.	1.10	.32	1.26	.56	.67	1.32
ADULTES	1.05	.76	1.45	.51	.72	1.39
	R	D	N			
5-6 Y.O.	.47	.69	.71			
9-10 Y.O.	.77	.93	1.16			
14-15 Y.O.	.90	.77	1.26			
ADULTES	.73	.74	1.05			

TABLE 1.8. : U (CS) : means and standard deviations in each experimental group and in each age group

MEANS - INCORRECT SEQUENCES UNCERTAINTY U(IS)

	N	N	N	N	R	N
5-6 Y.O.	1.94	1.59	1.24	1.67	2.48	1.59
9-10 Y.O.	1.16	.64	.58	.86	2.79	.63
14-15 Y.O.	1.05	.73	.46	.71	2.12	.25
ADULTES	.88	.78	.53	.96	1.88	.36

	N	D	N	D	R	N
5-6 Y.O.	1.09	1.48	.98	1.93	2.23	1.33
9-10 Y.O.	1.13	1.16	.63	1.78	2.72	.89
14-15 Y.O.	.76	.72	.13	1.04	1.26	.33
ADULTES	.94	.50	.47	.98	2.36	.12

	R	D	N
5-6 Y.O.	1.93	2.07	1.60
9-10 Y.O.	3.11	1.93	.98
14-15 Y.O.	2.81	1.33	.77
ADULTES	2.47	1.29	.49

STANDARD DEVIATIONS - INCORRECT SEQUENCES UNCERTAINTY U(IS)

	N	N	N	N	R	N
5-6 Y.O.	1.07	.94	1.06	1.15	1.29	1.23
9-10 Y.O.	1.03	.95	.96	.95	.79	1.04
14-15 Y.O.	1.03	.92	.72	.94	1.14	.53
ADULTES	.96	.77	.71	.84	1.18	.76

	N	D	N	D	R	N
5-6 Y.O.	.90	.92	1.17	.89	.72	.99
9-10 Y.O.	.74	.94	.75	1.00	.75	.97
14-15 Y.O.	.86	.73	.41	.96	1.25	.67
ADULTES	.94	.84	.69	1.11	.83	.40

	R	D	N
5-6 Y.O.	1.14	.92	.97
9-10 Y.O.	.50	.95	.83
14-15 Y.O.	.55	1.11	.96
ADULTES	.80	.83	.76

TABLE 1.9. : U(IS) : means and standard deviations in each experimental group and in each age group

MEANS -				MEAN REALIZATION TIME (MTR)		
	N	N	N	N	R	N
5-6 Y.O.	4.96	3.00	2.21	5.02	5.17	4.05
9-10 Y.O.	3.46	1.59	1.73	3.13	4.06	1.86
14-15 Y.O.	3.48	1.49	1.29	1.98	3.56	1.21
ADULTES	2.34	1.31	1.20	1.69	4.15	.97
	N	D	N	D	R	N
5-6 Y.O.	6.47	4	3.22	6.08	4.30	3.08
9-10 Y.O.	2.98	2.29	1.84	4.11	3.61	2.05
14-15 Y.O.	1.89	1.71	1.13	2.65	3.08	1.15
ADULTES	2.10	2.19	1.22	2.88	3.40	2.92
	R	D	N			
5-6 Y.O.	5.77	4.36	3.55			
9-10 Y.O.	5.44	2.71	2.09			
14-15 Y.O.	3.96	2.05	1.28			
ADULTES	5.61	2.19	1.46			

STANDARD DEVIATIONS -				MEAN REALIZATION TIME (MTR)		
	N	N	N	N	R	N
5-6 Y.O.	1.92	1.18	1.12	2.47	2.25	3.47
9-10 Y.O.	1.89	.74	1.64	1.69	1.86	1.13
14-15 Y.O.	3.03	1.12	.71	1.04	1.33	.71
ADULTES	1.76	.76	.65	1.20	2.10	.37
	N	D	N	D	R	N
5-6 Y.O.	3.80	2.07	1.65	2.45	1.21	1.15
9-10 Y.O.	2.03	1.02	1.32	1.25	1.62	1.26
14-15 Y.O.	1.40	.72	.36	1.66	1.09	.50
ADULTES	1.64	1.23	.48	1.75	1.73	4.05
	R	D	N			
5-6 Y.O.	2.69	2.22	1.98			
9-10 Y.O.	2.77	.92	1.02			
14-15 Y.O.	1.71	.87	.71			
ADULTES	3.55	.94	.58			

TABLE 1.10. : MTR : means and standard deviations in each experimental group and in each age group

MEANS -				MEAN LATENCY TIME (MTL)		
	N	N	N	N	R	N
5-6 Y.O.	2.26	1.27	1.53	2.27	2.22	2.24
9-10 Y.O.	1.22	.81	.93	1.06	1.16	.92
14-15 Y.O.	1.38	.74	.74	.82	.91	.60
ADULTES	.94	.73	.60	.73	1.03	.62
	N	D	N	D	R	N
5-6 Y.O.	1.99	2.84	1.74	2.58	1.79	1.76
9-10 Y.O.	1.25	.95	.92	1.69	1.25	1.28
14-15 Y.O.	.90	.88	.84	.93	.81	.84
ADULTES	1.02	.97	.75	1.06	1.01	.68
	R	D	N			
5-6 Y.O.	1.87	1.73	1.56			
9-10 Y.O.	1.80	1.06	1.21			
14-15 Y.O.	1.35	.83	.67			
ADULTES	1.73	1.48	.77			

STANDARD DEVIATIONS -				MEAN LATENCY TIME (MTL)		
	N	N	N	N	R	N
5-6 Y.O.	.93	.48	.81	1.35	1.29	1.46
9-10 Y.O.	.40	.18	.36	.48	.66	.43
14-15 Y.O.	1.13	.38	.32	.37	.42	.23
ADULTES	.65	.34	.18	.36	.46	.19
	N	D	N	D	R	N
5-6 Y.O.	1.04	1.88	1.10	1.22	.61	.75
9-10 Y.O.	.91	.55	.61	.62	.57	1.33
14-15 Y.O.	.52	.37	.43	.36	.35	.74
ADULTES	1.16	.41	.41	.49	.31	.28
	R	D	N			
5-6 Y.O.	.84	.68	.35			
9-10 Y.O.	1.14	.66	1.47			
14-15 Y.O.	.96	.58	.38			
ADULTES	1.22	1.50	.31			

<u>TABLE 1.11.</u>: **MTL : means and standard deviations in each experimental group and in each age group**

% CORRECT SEQUENCE (%CS)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	77.06	78.35	76.92	81.73	58.66	86.87
9-10 Y.O.	89.61	51.52	89	94.26	67.55	91.15
14-15 Y.O.	93.92	65.61	92.57	95.29	80.11	96.75
ADULTS	92.55	75.78	91.80	93.33	80.50	96.84

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	87.20	75.55	89.62	88.15	78.82
9-10 Y.O.	92.90	93.77	95.75	92.82	94.58
14-15 Y.O.	96.23	97.40	99.05	97.42	92.87
ADULTS	91.52	97.50	96.10	94.10	97.17

	nR	dR	nD	rD
5-6 Y.O.	58.66	73.69	86.87	71.17
9-10 Y.O.	67.55	61.41	91.15	82.82
14-15 Y.O.	80.11	86.28	96.75	87.52
ADULTS	80.50	82.20	96.84	93.26

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	75.42	79.20	82.22	74	73	80
9-10 Y.O.	91.93	87.21	56	46.50	92.28	86.80
14-15 Y.O.	94.10	93.50	65.80	65.30	94.40	91.10
ADULTS	93.50	91.90	81	72	94	90.60

TABLE 1.12. :% CS : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

% DOMINANT SEQUENCE (%DS)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	60.48	49.52	36.92	67.46	44.11	49.50
9-10 Y.O.	59.54	27.40	23.80	64.80	45.44	33.36
14-15 Y.O.	53.57	46	20.57	54.58	59.20	20.52
ADULTS	57.70	57.70	20.70	62.47	51.60	21.80

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	67.86	55.88	70.50	68.92	61.52
9-10 Y.O.	66.80	73.77	55.57	38.94	48.82
14-15 Y.O.	54.70	74.80	39.47	53.04	45.52
ADULTS	63.71	61.10	43.20	49.10	44.73

	nR	dR	nD	rD
5-6 Y.O.	44.11	50.46	49.50	40.94
9-10 Y.O.	45.44	36.94	33.36	31.17
14-15 Y.O.	59.20	62.66	20.52	24.47
ADULTS	51.60	61.80	21.80	28.52

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	60.78	60	48.44	50.75	40.33	34
9-10 Y.O.	57.24	61.90	32.22	22	21.42	25.60
14-15 Y.O.	55.42	49.66	51	39.55	20.80	20.30
ADULTS	60.60	55.80	64	53.20	21.10	20.40

TABLE 1.13. :% DS : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

NB CORRECT DIFFERENT SEQUENCES (NCS)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	4.65	5.40	6.60	3.93	5.72	5.25
9-10 Y.O.	5.90	8.20	11.40	4.20	6.94	8.57
14-15 Y.O.	6.90	6.40	13.30	5.76	5.35	13.63
ADULTS	6.65	5.15	13	6	6.80	13.55

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	3.86	4.50	4.06	4.46	4.52
9-10 Y.O.	4.60	4.83	6.89	9.70	7.76
14-15 Y.O.	5.94	3.25	9.73	7.66	7.70
ADULTS	5.09	6.45	10.15	8	7.05

	nR	dR	nD	rD
5-6 Y.O.	5.72	5.76	5.25	5.82
9-10 Y.O.	6.94	7.70	8.57	9.58
14-15 Y.O.	5.35	4.47	13.63	10.47
ADULTS	6.80	4.60	13.55	8.89

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	4.50	4.80	5.50	5.20	5.60	7.40
9-10 Y.O.	6	5.80	7.50	9	12.80	10.40
14-15 Y.O.	6.50	7.60	5.90	7.20	13.10	13.50
ADULTS	5	7.60	4.20	5.80	13.40	12.80

<u>TABLE 1.14.</u> :NCS : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

NB INCORRECT DIFFERENT SEQUENCES (NIS)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	4.69	5.70	5.15	4.33	9.33	3.62
9-10 Y.O.	2.80	11.40	4.30	2.05	9.16	2.84
14-15 Y.O.	2.14	9.47	2.61	1.82	6.40	1.63
ADULTS	2.30	7.30	2.90	2	5.70	1.40

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	3.26	5.22	3.06	3.30	4.41
9-10 Y.O.	2.10	2.16	1.62	2.41	2.17
14-15 Y.O.	1.47	.95	.47	1	2.14
ADULTS	1.61	1.05	1.36	1.30	1.26

	nR	dR	nD	rD
5-6 Y.O.	9.33	6.53	3.62	6.29
9-10 Y.O.	9.16	9.17	2.84	5.11
14-15 Y.O.	6.40	3.71	1.63	3.66
ADULTS	5.70	6.40	1.40	2.84

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	4.40	5	5.60	5.70	5.50	4.80
9-10 Y.O.	2.40	3.20	10.30	12.60	3.40	4.90
14-15 Y.O.	1.97	2.50	8.60	10.50	2.30	2.80
ADULTS	1.80	2.60	6.20	8.10	2	3.30

<u>TABLE 1.15.</u> : NIS : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

NB. SEQUENCES DIFF. 2 PREV. (NSD2)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	11.10	14.64	17.23	9.13	12.55	16
9-10 Y.O.	15.35	15.58	31	11.93	14.16	24.94
14-15 Y.O.	18.25	11.52	35.85	19.70	11.45	38.42
ADULTS	14.81	9.36	35.85	14.09	14	37.95

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	10.20	10.77	10.06	12	11.05
9-10 Y.O.	11.30	10.22	19.84	27	20.17
14-15 Y.O.	20.41	9.55	32.15	21.09	25.70
ADULTS	13.23	17.60	27.20	22.90	26.89

	nR	dR	nD	rD
5-6 Y.O.	12.55	15	16	15.64
9-10 Y.O.	14.16	17.11	24.94	25
14-15 Y.O.	11.45	11.33	38.42	29.66
ADULTS	14	9.95	37.95	31.15

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	10.89	11.38	16.77	12.25	14.33	19.71
9-10 Y.O.	16.79	13.85	15.33	15.87	31.28	30.90
14-15 Y.O.	16.63	21.66	10.25	13.22	36.11	35.66
ADULTS	13.16	15.89	8.37	10.09	36.57	35.46

TABLE 1.16. : NSD_2 : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

SEQUENCES UNCERTAINTY (U(S))

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	1.80	2.20	2.60	1.57	2.72	2.10
9-10 Y.O.	1.86	3.59	3.34	1.44	2.87	2.74
14-15 Y.O.	1.97	2.81	3.52	1.81	2.10	3.45
ADULTS	1.89	2.21	3.48	1.67	2.34	3.38

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	1.45	1.97	1.36	1.54	1.79
9-10 Y.O.	1.40	1.25	1.90	2.68	2.16
14-15 Y.O.	1.78	.96	2.53	1.94	2.32
ADULTS	1.53	1.66	2.48	2.12	2.12

	nR	dR	nD	rD
5-6 Y.O.	2.72	2.44	2.10	2.54
9-10 Y.O.	2.87	3.23	2.74	3.08
14-15 Y.O.	2.10	1.66	3.45	3.21
ADULTS	2.34	1.96	3.38	2.89

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	1.80	1.90	2.30	2.20	2.50	2.80
9-10 Y.O.	1.89	1.84	3.32	3.88	3.40	3.25
14-15 Y.O.	1.86	2.22	2.58	3.12	3.43	3.58
ADULTS	1.58	2.08	1.90	2.40	3.47	3.48

TABLE 1.17. : U (S) : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

CORRECT SEQUENCES UNCERTAINTY (U(CS))

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	1.15	1.46	1.97	.95	1.68	1.55
9-10 Y.O.	1.49	2.27	2.94	1.17	1.73	2.41
14-15 Y.O.	1.73	1.57	3.29	1.61	1.31	3.33
ADULTS	1.59	1.20	3.24	1.42	1.62	3.29

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	.92	1.30	.92	1	1.05
9-10 Y.O.	1.18	1.02	1.71	2.40	1.94
14-15 Y.O.	1.60	.82	2.49	1.84	2.01
ADULTS	1.23	1.54	2.35	1.93	1.99

	nR	dR	nD	rD
5-6 Y.O.	1.68	1.58	1.55	1.69
9-10 Y.O.	1.73	2.16	2.41	2.52
14-15 Y.O.	1.31	1.12	3.33	2.76
ADULTS	1.62	1.05	3.29	2.59

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	1.13	1.17	1.52	1.39	1.59	2.29
9-10 Y.O.	1.54	1.44	2.12	2.43	3.20	2.77
14-15 Y.O.	1.62	1.94	1.39	1.81	3.25	3.32
ADULTS	1.34	1.76	.95	1.38	3.29	3.21

TABLE 1.18.: U(CS) : - means as a function of age and of presentation order of matrix type
- means as a function of age and of sex, in the first session (F = females; M = males)

INCORRECT SEQUENCES UNCERTAINTY (U(IS))

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	1.56	1.93	1.93	1.59	2.48	1.48
9-10 Y.O.	1.06	3.11	1.78	.64	2.79	1.16
14-15 Y.O.	.83	2.84	1.04	.73	2.12	.72
ADULTS	.93	2.47	.98	.78	1.88	.50

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	1.24	1.59	.98	1.33	1.60
9-10 Y.O.	.58	.63	.63	.89	.98
14-15 Y.O.	.46	.25	.13	.33	.77
ADULTS	.53	.36	.47	.12	.49

	nR	dR	nD	rD
5-6 Y.O.	2.48	2.23	1.48	2.07
9-10 Y.O.	2.79	2.72	1.16	1.93
14-15 Y.O.	2.12	1.26	.72	1.33
ADULTS	1.88	2.36	.50	1.29

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	1.48	1.67	2.07	1.78	2.08	1.79
9-10 Y.O.	.89	1.23	2.95	3.29	1.53	1.95
14-15 Y.O.	.76	.96	2.63	3.12	.90	1.15
ADULTS	.65	1.11	2.22	2.66	.67	1.15

TABLE 1.19.: U(IS) : - means as a function of age and of presentation order of matrix type
- means as a function of age and of sex, in the first session (F = females; M = males)

MEAN REALIZATION TIME (MTR)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	5.47	5.77	6.08	3	5.17	4
9-10 Y.O.	3.20	5.44	4.11	1.59	4.06	2.29
14-15 Y.O.	2.40	3.90	2.62	1.49	3.56	1.71
ADULTS	2.05	5.65	2.80	1.31	4.15	2.19

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	2.21	4.05	3.22	3.08	3.55
9-10 Y.O.	1.73	1.86	1.84	2.05	2.09
14-15 Y.O.	1.29	1.21	1.13	1.15	1.28
ADULTS	1.20	.97	1.22	2.92	1.46

	nR	dR	nD	rD
5-6 Y.O.	5.17	4.30	4	4.36
9-10 Y.O.	4.06	3.61	2.29	2.71
14-15 Y.O.	3.56	3.08	1.71	2.05
ADULTS	4.15	3.40	2.19	2.19

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	5.55	5.37	6.12	5.38	7.03	5.26
9-10 Y.O.	3.30	3	5.74	5.10	4.65	3.74
14-15 Y.O.	2.57	2.04	4.41	3.36	3.52	1.94
ADULTS	1.88	2.16	5.09	6.03	2.59	2.91

TABLE 1.20. : MTR : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

MEAN LATENCY TIME (MTL)

	GNxx	Rxx	Dxx	nN	nR	nD
5-6 Y.O.	2.18	1.87	2.58	1.27	2.22	2.84
9-10 Y.O.	1.18	1.80	1.69	.81	1.16	.95
14-15 Y.O.	1.02	1.26	.93	.74	.91	.88
ADULTS	.90	1.73	1.06	.73	1.03	.97

	nnN	nrN	ndN	drN	rdN
5-6 Y.O.	1.53	2.24	1.74	1.76	1.56
9-10 Y.O.	.93	.92	.92	1.28	1.21
14-15 Y.O.	.74	.60	.84	.84	.67
ADULTS	.60	.62	.75	.68	.77

	nR	dR	nD	rD
5-6 Y.O.	2.22	1.79	2.84	1.73
9-10 Y.O.	1.16	1.25	.95	1.06
14-15 Y.O.	.91	.81	.88	.83
ADULTS	1.03	1.01	.97	1.48

	F-GNxx	M-GNxx	F-Rxx	M-Rxx	F-Dxx	M-Dxx
5-6 Y.O.	2.50	1.74	1.71	2.05	2.35	2.78
9-10 Y.O.	1.19	1.18	1.54	2.09	1.58	1.76
14-15 Y.O.	1.11	.83	1.39	1.10	1.11	.79
ADULTS	.70	1.03	1.30	2	1.09	1.04

TABLE 1.21. : MTL : - means as a function of age and of presentation order of matrix type

- means as a function of age and of sex, in the first session (F = females; M = males)

CONDITIONAL UNCERTAINTY OF RESPONSES (U(R/s)

	R1	R2	R3	R4	R5	R6
			GN			
5-6 Y.O.	.54	.37	.32	.36	.19	.10
9-10 Y.O.	.65	.38	.38	.24	.13	.05
14-15 Y.O.	.72	.42	.39	.25	.12	.03
ADULTS	.65	.46	.36	.24	.10	.04
			R			
5-6 Y.O.	.79	.38	.38	.25	.23	.21
9-10 Y.O.	.84	.70	.59	.56	.54	.42
14-15 Y.O.	.65	.61	.54	.42	.37	.23
ADULTS	.62	.44	.41	.35	.22	.16
			D			
5-6 Y.O.	.80	.52	.40	.49	.29	.20
9-10 Y.O.	.89	.77	.78	.44	.32	.11
14-15 Y.O.	.92	.88	.75	.49	.37	.07
ADULTS	.93	.89	.81	.46	.29	.06

TABLE 1.22. : Means of the U(R1) and U(R/s) as a function of age and of matrix type, in the first session

Tab. 1.23. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NNN among the 5-6 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	N	N	N
N			
N	**		
N	*	N.S.	

% DS			
	*		
	*	N.S.	

NCS			
	*		
	*	N.S.	

NIS			
	N.S.		
	**	N.S.	

U(S)			
	*		
	**	N.S.	

U(CS)			
	N.S.		
	*	N.S.	

U(IS)			
	N.S.		
	**	*	

NSD2			
	*		
	N.S.	N.S.	

MTR			
	**		
	**	*	

MTL			
	**		
	**	N.S.	

Tab. 1.24. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NNN among the 9-10 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	N	N	N
N			
N	**		
N	**	N.S.	

% DS			
	N.S.		
	N.S.	N.S.	

NCS			
	**		
	**	N.S.	

NIS			
	N.S.		
	N.S.	N.S.	

U(S)			
	**		
	**	N.S.	

U(CS)			
	**		
	*	N.S.	

U(IS)			
	*		
	*	N.S.	

NSD2			
	**		
	*	N.S.	

MTR			
	**		
	**	N.S.	

MTL			
	**		
	**	*	

Tab. 1.25. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NNN among the 14-15 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	N	N	N
N			
N	N.S.		
N	*	N.S.	

% DS

N.S.		
N.S.	N.S.	

NCS

N.S.		
N.S.	N.S.	

NIS

N.S.		
**	N.S.	

U(S)

N.S.		
N.S.	N.S.	

U(CS)

N.S.		
N.S.	N.S.	

U(IS)

N.S.		
*	*	

NSD2

N.S.		
N.S.	N.S.	

MTR

**		
**	N.S.	

MTL

**		
**	N.S.	

Tab. 1.26. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NNN among the adults. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	N	N	N
N			
N	N.S.		
N	N.S.	N.S.	

% DS			
	N.S.		
	N.S.	N.S.	

NCS			
	N.S.		
	N.S.	N.S.	

NIS			
	N.S.		
	N.S.	N.S.	

U(S)			
	N.S.		
	N.S.	N.S.	

U(CS)			
	N.S.		
	N.S.	N.S.	

U(IS)			
	N.S.		
	*	N.S.	

NSD2			
	N.S.		
	N.S.	N.S.	

MTR			
	**		
	**	N.S.	

MTL			
	N.S.		
	*	*	

Tab. 1.27. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NRN among the 5-6 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	N	R	N
N			
R	**		
N	N.S.	**	

% DS	N	R	N
N			
R	N.S.		
N	N.S.	N.S.	

NCS	N	R	N
N			
R	N.S.		
N	N.S.	N.S.	

NIS	N	R	N
N			
R	**		
N	N.S.	*	

U(S)	N	R	N
N			
R	*		
N	N.S.	*	

U(CS)	N	R	N
N			
R	N.S.		
N	N.S.	N.S.	

U(IS)	N	R	N
N			
R	*		
N	N.S.	*	

NSD2	N	R	N
N			
R	N.S.		
N	N.S.	N.S.	

MTR	N	R	N
N			
R	N.S.		
N	N.S.	N.S.	

MTL	N	R	N
N			
R	N.S.		
N	N.S.	N.S.	

Tab. 1.28. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NRN among the 9-10y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	N	R	N
N			
R	**		
N	N.S.	**	

% DS

*		
**	**	

NCS

N.S.		
N.S.	*	

NIS

**		
N.S.	**	

U(S)

**		
*	**	

U(CS)

N.S.		
N.S.	*	

U(IS)

**		
N.S.	**	

NSD2

N.S.		
N.S.	N.S.	

MTR

**		
**	**	

MTL

N.S.		
N.S.	**	

Tab. 1.29. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NRN among the 14-15 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	N	R	N
N			
R	**		
N	N.S.	**	

% DS

	N	R	N
N			
R	N.S.		
N	**	*	

NCS

	N	R	N
N			
R	N.S.		
N	**	**	

NIS

	N	R	N
N			
R	**		
N	*	**	

U(S)

	N	R	N
N			
R	N.S.		
N	**	**	

U(CS)

	N	R	N
N			
R	N.S.		
N	**	*	

U(IS)

	N	R	N
N			
R	**		
N	N.S.	**	

NSD2

	N	R	N
N			
R	*		
N	**	N.S.	

MTR

	N	R	N
N			
R	**		
N	**	**	

MTL

	N	R	N
N			
R	N.S.		
N	*	**	

Tab. 1.30. For each index, level of signification of the student *T*-tests for related samples for the 3 sessions of the experimental group NRN among the adults. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	N	R	N
N			
R	*		
N	*	**	

% DS

N.S.		
N.S.	N.S.	

NCS

N.S.		
N.S.	N.S.	

NIS

**		
*	**	

U(S)

N.S.		
N.S.	N.S.	

U(CS)

N.S.		
N.S.	N.S.	

U(IS)

**		
N.S.	**	

NSD2

N.S.		
N.S.	N.S.	

MTR

**		
*	**	

MTL

**		
*	**	

Tab. 1.31. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NDN among the 5-6 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	N	D	N
N			
D	N.S.		
N	*	N.S.	

% DS

	N	D	N
N			
D	**		
N	N.S.	**	

NCS

	N	D	N
N			
D	*		
N	N.S.	N.S.	

NIS

	N	D	N
N			
D	N.S.		
N	N.S.	N.S.	

U(S)

	N	D	N
N			
D	**		
N	N.S.	*	

U(CS)

	N	D	N
N			
D	**		
N	N.S.	*	

U(IS)

	N	D	N
N			
D	N.S.		
N	N.S.	*	

NSD2

	N	D	N
N			
D	**		
N	N.S.	**	

MTR

	N	D	N
N			
D	N.S.		
N	**	*	

MTL

	N	D	N
N			
D	*		
N	N.S.	**	

Tab. 1.32. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NDN among the 9-10 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	N	D	N
N			
D	N.S.		
N	**	**	

% DS

**		
N.S.	**	

NCS

**		
N.S.	N.S.	

NIS

N.S.		
*	*	

U(S)

**		
N.S.	**	

U(CS)

**		
N.S.	**	

U(IS)

N.S.		
*	*	

NSD2

**		
*	*	

MTR

N.S.		
**	*	

MTL

N.S.		
**	N.S.	

Tab. 1.33. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NDN among the 14-15 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	N	D	N
N			
D	*		
N	**	**	

% DS

**		
N.S.	**	

NCS

**		
N.S.	**	

NIS

N.S.		
*	**	

U(S)

**		
N.S.	**	

U(CS)

**		
N.S.	**	

U(IS)

N.S.		
*	**	

NSD2

**		
**	*	

MTR

N.S.		
**	**	

MTL

N.S.		
N.S.	N.S.	

Tab. 1.34. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group NDN among the adults. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	N	D	N
N			
D	**		
N	*	N.S.	

% DS

	**		
	N.S.	**	

NCS

	**		
	*	**	

NIS

	*		
	**	N.S.	

U(S)

	**		
	**	N.S.	

U(CS)

	**		
	*	**	

U(IS)

	*		
	**	N.S.	

NSD2

	**		
	**	*	

MTR

	N.S.		
	**	**	

MTL

	N.S.		
	N.S.	*	

Tab. 1.35. For each index, level of signification of the student T tests for related samples for the 3 sessions of the experimental group DRN among the 5-6 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	D	R	N
D			
R	N.S.		
N	**	*	

% DS

*		
**	**	

NCS

N.S.		
**	*	

NIS

N.S.		
N.S.	**	

U(S)

N.S.		
**	**	

U(CS)

*		
**	**	

U(IS)

N.S.		
N.S.	*	

NSD2

N.S.		
**	*	

MTR

**		
**	**	

MTL

*		
*	N.S.	

Tab. 1.36. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group DRN among the 9-10 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	D	R	N
D			
R	**		
N	*	**	

% DS

	D	R	N
D			
R	*		
N	**	N.S.	

NCS

	D	R	N
D			
R	*		
N	*	N.S.	

NIS

	D	R	N
D			
R	**		
N	**	**	

U(S)

	D	R	N
D			
R	N.S.		
N	**	N.S.	

U(CS)

	D	R	N
D			
R	*		
N	**	N.S.	

U(IS)

	D	R	N
D			
R	**		
N	**	**	

NSD2

	D	R	N
D			
R	**		
N	*	**	

MTF

	D	R	N
D			
R	N.S.		
N	**	**	

MTL

	D	R	N
D			
R	N.S.		
N	*	N.S.	

Tab. 1.37. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group DRN among the 14-15 y.o. (* p ≤ .05 ; ** p ≤ .01 ; N.S. = no significant).

% CS	D	R	N
D			
R	N.S.		
N	**	**	

% DS	D	R	N
D			
R	**		
N	**	N.S.	

NCS	D	R	N
D			
R	**		
N	**	**	

NIS	D	R	N
D			
R	N.S.		
N	**	**	

U(S)	D	R	N
D			
R	**		
N	**	N.S.	

U(CS)	D	R	N
D			
R	**		
N	**	**	

U(IS)	D	R	N
D			
R	N.S.		
N	**	**	

NSD2	D	R	N
D			
R	**		
N	**	**	

MTR	D	R	N
D			
R	N.S.		
N	**	**	

MTL	D	R	N
D			
R	N.S.		
N	N.S.	N.S.	

Tab. 1.38. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group DRN among the adults. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	D	R	N
D			
R	**		
N	N.S.	**	

% DS	D	R	N
D			
R	**		
N	**	N.S.	

NCS	D	R	N
D			
R	**		
N	**	**	

NIS	D	R	N
D			
R	**		
N	N.S.	**	

U(S)	D	R	N
D			
R	**		
N	**	N.S.	

U(CS)	D	R	N
D			
R	**		
N	**	*	

U(IS)	D	R	N
D			
R	**		
N	N.S.	**	

NSD2	D	R	N
D			
R	**		
N	**	**	

MTR	D	R	N
D			
R	N.S.		
N	N.S.	**	

MTL	D	R	N
D			
R	N.S.		
N	**	**	

Tab. 1.39. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group RDN among the 5-6 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	R	D	N
R			
D	N.S.		
N	N.S.	N.S.	

% DS	R	D	N
R			
D	*		
N	**	**	

NCS	R	D	N
R			
D	N.S.		
N	N.S.	*	

NIS	R	D	N
R			
D	N.S.		
N	N.S.	*	

U(S)	R	D	N
R			
D	*		
N	**	**	

U(CS)	R	D	N
R			
D	N.S.		
N	**	**	

U(IS)	R	D	N
R			
D	N.S.		
N	N.S.	*	

NSD2	R	D	N
R			
D	N.S.		
N	*	*	

MTR	R	D	N
R			
D	N.S.		
N	**	**	

MTL	R	D	N
R			
D	N.S.		
N	N.S.	N.S.	

Tab. 1.40. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group *RDN among* the 9-10 y.o. (*: $p \leq .05$; **: $p \leq .01$; N.S. = no significant).

% CS	R	D	N
R			
D	**		
N	**	**	

% DS

N.S.		
**	**	

NCS

N.S.		
N.S.	**	

NIS

**		
**	**	

U(S)

*		
**	**	

U(CS)

N.S.		
N.S.	**	

U(IS)

**		
**	**	

NSD2

**		
N.S.	*	

MTR

**		
**	*	

MTL

*		
N.S.	N.S.	

Tab. 1.41. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group RDN among the 14-15 y.o. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS	R	D	N
R			
D	**		
N	**	**	

% DS			
	**		
	N.S.	**	

NCS			
	**		
	N.S.	**	

NIS			
	**		
	**	*	

U(S)			
	N.S.		
	N.S.	**	

U(CS)			
	**		
	N.S.	**	

U(IS)			
	**		
	**	*	

NSD2			
	**		
	**	N.S.	

MTR			
	**		
	**	**	

MTL			
	*		
	N.S.	*	

Tab. 1.42. For each index, level of signification of the student T-tests for related samples for the 3 sessions of the experimental group RDN among the adults. (*:p ≤ .05 ; **:p ≤ .01 ; N.S. = no significant).

% CS

	R	D	N
R			
D	**		
N	**	**	

% DS

**		
*	**	

NCS

**		
N.S.	*	

NIS

**		
**	*	

U(S)

**		
N.S.	**	

U(CS)

**		
**	**	

U(IS)

**		
**	**	

NSD2

**		
**	*	

MTR

**		
**	**	

MTL

N.S.		
**	*	

% CORRECT SEQUENCES (%CS)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 11.29	p< .0000
	FACTOR MATRIX	F(2,352)= 62.85	p< .0000
	AGE X MATRIX	F(6,352)= 9.52	p< .0000
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=9.69	p< .0000
	FACTOR MATRIX	F(2,207)=37.22	p< .0000
	AGE X MATRIX	F(6,207)=9.62	p< .0000

% DOMINANT SEQUENCE (%DS)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 2.48	p< .06
	FACTOR MATRIX	F(2,352)= 66.16	p< .0000
	AGE X MATRIX	F(6,352)= 3.49	p< .002
PRE-TRAINED SUBJECTS	FACTOR AGE	NS	
	FACTOR MATRIX	F(2,207)= 41.33	p< .0000
	AGE X MATRIX	F(6,207)= 4.29	p< .0000

NB CORRECT DIFFERENT SEQUENCES (NCS)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 9.3	p< .0000
	FACTOR MATRIX	F(2,352)= 61.13	p< .0000
	AGE X MATRIX	F(6,352)= 3.90	p< .002
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=12.85	p< .0000
	FACTOR MATRIX	F(2,207)= 53.06	p< .0000
	AGE X MATRIX	F(6,207)= 7.75	p< .0000

NB.INCORRECT DIFFERENT SEQUENCES (N S)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 6.09	p< .0000
	FACTOR MATRIX	F(2,352)=110.13	p< .0000
	AGE X MATRIX	F(6,352)=9.5	p< .0000
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=8.10	p< .0000
	FACTOR MATRIX	F(2,207)=58.94	p< .0000
	AGE X MATRIX	F(6,207)=	NS

NB SEQUENCES DIFFERENT 2 PREVIOUS (NSD2)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 8.55	p< .0000
	FACTOR MATRIX	F(2,352)=101.4	p< .0000
	AGE X MATRIX	F(6,352)=6.37	p< .0000
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=17.27	p< .0000
	FACTOR MATRIX	F(2,207)=98.58	p< .0000
	AGE X MATRIX	F(6,207)=9.15	p< .0000

TABLE 1.43 : %CS, %DS, NCS, NIS, NSD2: ANOVA (age x matrix) in the first and in the second sessions (after N).

SEQUENCES UNCERTAINTY (U(S)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 2.50	p<.059
	FACTOR MATRIX	F(2,352)= 61.03	p<.0000
	AGE X MATRIX	F(6,352)=3.65	p<.002
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=	NS
	FACTOR MATRIX	F(2,207)=34.04	p<.0000
	AGE X MATRIX	F(6,207)=4.59	p<.0000

CORRECT SEQUENCES UNCERTAINTY (U(CS))

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 7.16	p<.0000
	FACTOR MATRIX	F(2,352)= 69.14	p<.0000
	AGE X MATRIX	F(6,352)= 3.84	p<.001
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)= 6.57	p<.0000
	FACTOR MATRIX	F(2,207)= 53.61	p<.0000
	AGE X MATRIX	F(6,207)= 6.52	p<.0000

INCORRECT SEQUENCES UNCERTAINTY (U(IS))

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 4.95	p<.002
	FACTOR MATRIX	F(2,352)= 73.74	p<.0000
	AGE X MATRIX	F(6,352)= 5.41	p<.0000
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=7.34	p<.0000
	FACTOR MATRIX	F(2,207)= 50.08	p<.0000
	AGE X MATRIX	F(6,207)=	NS

MEAN REALIZATION TIME (MTR)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)= 29.41	p<.0000
	FACTOR MATRIX	F(2,352)=23.45	p<.0000
	AGE X MATRIX	F(6,352)=2.8	p<.01
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=14.94	p<.0000
	FACTOR MATRIX	F(2,207)=51.89	p<.0000
	AGE X MATRIX	F(6,207)=	NS

MEAN LATENCY TIME (MTL)

ANOVA (AGE X MATRIX)			
NAIVE SUBJECTS	FACTOR AGE	F(3,352)=30.16	p<.0000
	FACTOR MATRIX	F(2,352)=5.58	p<.004
	AGE X MATRIX	F(6,352)=3.11	p<.006
PRE-TRAINED SUBJECTS	FACTOR AGE	F(3,207)=34.33	p<.0000
	FACTOR MATRIX	F(2,207)=9.09	p<.0000
	AGE X MATRIX	F(6,207)=3.6	p<.002

TABLE 1.44 : U(S), U(CS), U(IS), MTR, MTL: ANOVA (age x matrix) in the first and in the second sessions (after N).

% CORRECT SEQUENCES (%CS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,74)=.02 NS				X2=36.49 p< .0000				X2=41.37 p< .0000				X2=22.73 p< .0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= GN	1				1		*		1		*		1		*	
2= R	2				2				2				2			
3= D	3				3		*		3		*		3		*	

% DOMINANT SEQUENCE (%DS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,74)=6.1 p<0.003				X2=41.46 p< .0000				X2=31.68 p< .0000				X2=34.79 p< .0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= GN	1				1				1				1			*
2= R	2				2	*			2				2			
3= D	3	*			3	*			3	*	*		3			

NB. CORRECT DIFFERENT SEQUENCES (NCS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,74)=2.2 NS				X2=21.50 p< .0000				X2=28.11 p< .0000				X2=29.33 p< .0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= GN	1				1		*		1				1			
2= R	2				2				2				2			
3= D	3				3	*	*		3	*	*		3	*	*	

NB.INCORRECT DIFFERENT SEQUENCES (NIS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,74)=.4 NS				X2=39.48 p<0.0000				X2=42.24 p<0.0000				X2=26.66 p<0.0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= GN	1				1				1		*		1		*	
2= R	2				2	*			2				2			
3= D	3				3	*	*		3		*		3		*	

NB SEQUENCES DIFFERENT 2 PREVIOUS (NSD2)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,74)=3.9 p>.02				X2=22.89 p<0.0000				X2=36.89 p< .0000				X2=43.7 p< .0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= GN	1				1				1				1			
2= R	2				2				2	*			2			
3= D	3	*			3	*	*		3	*	*		3	*	*	

TABLE 1.45: %CS, %DS, NCS, NIS, NSD2: -ANOVA (matrix) and Newman-keuls test among the 5-6 Y.O., in the first session.
-Kruskal-Wallis (matrix) and Mann-Whitney tests among 9-10 Y.O., 14-15 Y.O, ADULTS, in the first session.
(*) indicates a significant difference with P<.05.

SEQUENCES UNCERTAINTY (U(S))

AGE	5-6 Y.O.			9-10 Y.O.			14-15 Y.O.			ADULTS		
	F(2,74)=3.2 p<.04			X2=40.44 p<.0000			X2=30.8 p<.0000			X2=28.77 p<.0000		
	1	2	3	1	2	3	1	2	3	1	2	3
1= GN (1)												
2= R (2)				*			*					
3= D (3)	*			*			*	*		*	*	

CORRECT SEQUENCES UNCERTAINTY (U(CS))

AGE	5-6 Y.O.			9-10 Y.O.			14-15 Y.O.			ADULTS		
	F(2,74)=4.5 p<0.01			X2=26.73 p<.0000			X2=32.67 p<.0000			X2=36.17 p<.0000		
	1	2	3	1	2	3	1	2	3	1	2	3
1= GN (1)												
2= R (2)				*								
3= D (3)	*			*	*		*	*		*	*	

INCORRECT SEQUENCES UNCERTAINTY (U(IS))

AGE	5-6 Y.O.			9-10 Y.O.			14-15 Y.O.			ADULTS		
	F(2,74)=.98 NS			X2=40.7 p<.0000			X2=39.94 p<.0000			X2=27.81 p<.0000		
	1	2	3	1	2	3	1	2	3	1	2	3
1= GN (1)												
2= R (2)				*			*		*	*		*
3= D (3)				*	*							

MEAN REALIZATION TIME (MTR)

AGE	5-6 Y.O.			9-10 Y.O.			14-15 Y.O.			ADULTS		
	F(2,74)=.37 NS			X2=18.30 p<0.0001			X2=17.19 p<0.0002			X2=30.14 p<0.0000		
	1	2	3	1	2	3	1	2	3	1	2	3
1= GN (1)								*				
2= R (2)				*						*		
3= D (3)				*				*		*	*	

MEAN LATENCY TIME (MTL)

AGE	5-6 Y.O.			9-10 Y.O.			14-15 Y.O.			ADULTS		
	F(2,74)=1.5 NS			X2=12.44 p<0.002			X2= NS			X2=20.03 p<.0000		
	1	2	3	1	2	3	1	2	3	1	2	3
1= GN (1)												
2= R (2)				*						*		
3= D (3)				*						*		

TABLE 1.46 : U(S), U(CS), U(IS), MTR, MTL: -ANOVA (matrix) and Neuwman-Keuls test among the 5-6 Y.O., in the first session.
-Kruskal-Wallis (matrix) and Mann-Whit ney tests among 9-10 Y.O., 14-15 Y.O, ADULTS, in the first session.
(*) indicates a significant difference with P<.05.

SUJETS PREENTRAINES

% CORRECT SEQUENCES (%CS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,42)=6.8 p<.003				F(2,54)=13. p<.0000				F(2,53)=10. p<.0001				F(2,59)=9.2 p<.0003			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1		*		1		*		1		*		1		*	
2= R	2				2				2				2			
3= D	3		*		3		*		3		*		3		*	

% DOMINANT SEQUENCE (%DS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,42)=6.5 p<0.003				F(2,54)=9.8 p<.0002				F(2,53)=19. p<.0000				F(2,59)=18. p<.0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1				1				1				1			
2= R	2	*			2	*			2	*			2	*		
3= D	3	*			3	*				*			3	*		

NB. CORRECT DIFFERENT SEQUENCES (NCS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,42)= NS				F(2,54)=9.7 p<.0002				F(2,53)=49. p<.0000				F(2,59)=18. p<.0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1				1				1				1			
2= R	2				2	*			2				2			
3= D	3				3	*			3	*	*		3	*	*	

NB. INCORRECT DIFFERENT SEQUENCES (NIS)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,42)=9.9 p<.0003				F(2,54)=25. p<0.0000				F(2,53)=13. p<0.0000				F(2,59)=13. p<0.0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1		*		1		*		1		*		1		*	
2= R	2				2				2				2			
3= D	3		*		3		*		3		*		3		*	

NB SEQUENCES DIFFERENT 2 PREVIOUS (NSD2)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	F(2,42)=5.2 p>.0009				F(2,54)=13. p<0.0000				F(2,53)=51. p<.0000				F(2,59)=42. p<.0000			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1				1				1				1			
2= R	2				2				2				2			
3= D	3	*	*		3	*	*		3	*	*		3	*	*	

TABLE 1.47 : %CS, %DS, NCS, NIS, NSD2: - ANOVA (matrix) and Neuwman-Keuls test for each age group, in the second session
(*) indicates a significant difference with P<.05.

SEQUENCES UNCERTAINTY (U(S))

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	$F(2,42)=5.9$				$F(2,54)=12.$				$F(2,53)=15.$				$F(2,59)=13.$			
	$p<.0005$				$p<.0000$				$p<.0000$				$p<.0000$			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1		*		1				1				1			
2= R	2				2	*			2				2	*		
3= D	3		*		3	*			3	*	*		3	*	*	

CORRECT SEQUENCES UNCERTAINTY (U(CS))

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	$F(2,42)=5.1$				$F(2,54)=9.8$				$F(2,53)=37.$				$F(2,59)=22.$			
	$p<0.01$				$p<.0002$				$p<.0000$				$p<.0000$			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1				1				1				1			
2= R	2	*			2				2				2			
3= D	3	*			3	*	*		3	*	*		3	*	*	

INCORRECT SEQUENCES UNCERTAINTY (U(IS))

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	$F(2,42)=4.1$				$F(2,54)=28.$				$F(2,53)=13.$				$F(2,59)=11.$			
	$p<.02$				$p<.0000$				$p<.0000$				$p<.0001$			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1		*		1		*		1		*		1		*	
2= R	2				2				2				2			
3= D	3		*		3		*		3		*		3		*	

MEAN REALIZATION TIME (MTR)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	$F(2,42)=4.6$				$F(2,54)=18.$				$F(2,53)=20.$				$F(2,59)=18.$			
	$p<.01$				$p<0.0000$				$p<0.0000$				$p<0.0000$			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1				1		*		1		*		1		*	
2= R	2	*			2				2				2			
3= D	3				3		*		3		*		3		*	

MEAN LATENCY TIME (MTL)

AGE	5-6 Y.O.				9-10 Y.O.				14-15 Y.O.				ADULTS			
	$F(2,42)=4.9$				$F(2,54)=$				$F(2,53)=$				$F(2,59)=3.2$			
	$P<.01$				NS				NS				$p<.0000$			
		1	2	3		1	2	3		1	2	3		1	2	3
1= N	1				1				1				1			
2= R	2	*			2				2				2			
3= D	3	*			3				3				3			

TABLE 1.48 : U(S), U(CS), U(IS), MTR, MTL: - ANOVA (matrix) and Neuwman-Keuls test for each age group, in the *second session*
(*) indicates a significant difference with $P<.05$.

% CORRECT SEQUENCES (%CS)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)= 15.4	p< .0000
FACTOR PRE-T.	F(4,344)=	NS
AGE X PRE-T	F(12,344)=	NS

% DOMINANT SEQUENCE (%DS)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)= 3.76	p< .01
FACTOR PRE-T.	F(4,344)= 6.43	p< .0000
AGE X PRE-T	F(12,344)= 1.94	p< .03

NB CORRECT DIFFERENT SEQUENCES (NCS)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=7.57	p< .0000
FACTOR PRE-T.	F(4,344)=8.1	p< .0000
AGE X PRE-T	F(12,344)= 1.82	p< .04

NB.INCORRECT DIFFERENT SEQUENCES (NIS)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)= 18.98	p< .0000
FACTOR PRE-T.	F(4,344)=	NS
AGE X PRE-T	F(12,344)=	NS

NB SEQUENCES DIFFERENT 2 PREVIOUS (NSD2)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=12.91	p< .0000
FACTOR PRE-T.	F(4,344)=10.68	p< .0000
AGE X PRE-T	F(12,344)=2.37	p< .006

TABLE 1.49 : %CS, %DS, NCS, NIS, NSD2: - ANOVA (age x pre-training) in the third session.

SEQUENCES UNCERTAINTY (U(S))

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=	NS
FACTOR PRE-T.	F(4,344)=6.26	p<.0000
AGE X PRE-T	F(12,344)=1.93	p<.03

CORRECT SEQUENCES UNCERTAINTY (U(CS))

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=8.37	p<.0000
FACTOR PRE-T.	F(4,344)=7.50	p<.0000
AGE X PRE-T	F(12,344)=2.12	p<.01

INCORRECT SEQUENCES UNCERTAINTY (U(IS))

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=22.31	p<.0000
FACTOR PRE-T.	F(4,344)=	NS
AGE X PRE-T	F(12,344)=	NS

MEAN REALIZATION TIME (MTR)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=29.64	p<.0000
FACTOR PRE-T.	F(4,344)=2.71	p<.03
AGE X PRE-T	F(12,344)=2.05	p<.02

MEAN LATENCY TIME (MTL)

ANOVA (AGE X PRE-TRAINING)		
FACTOR AGE	F(3,344)=40.23	p<.0000
FACTOR PRE-T.	F(4,344)=	NS
AGE X PRE-T	F(12,344)=	NS

TABLE 1.50 : U(S), U(CS), U(IS), MTR, MTL: - ANOVA (age x pre-training) in the third session.

% CORRECT SEQUENCES (%CS)

AGE	5-6 Y.O.					9-10 Y.O.					14-15 Y.O.					ADULTS				
	NS					NS					F(4,93)=3.1 p<.02					NS				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1= NNN																				
2= NRN																				
3= NDN																				
4= DRN																				
5= RDN												*	*							

% DOMINANT SEQUENCE (%DS)

AGE	5-6 Y.O.					9-10 Y.O.					14-15 Y.O.					ADULTS				
	NS					F(4,86)=4.9 p<.001					F(4,93)=4.6 p<.002					NS				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1= NNN									*											
2= NRN									*	*	*		*	*	*					
3= NDN																				
4= DRN																				
5= RDN																				

NB. CORRECT DIFFERENT SEQUENCES (NCS)

AGE	5-6 Y.O.					9-10 Y.O.					14-15 Y.O.					ADULTS				
	NS					F(4,86)=4.0 p<.005					F(4,93)=5.8 p<.0003					F(4,95)=2.5 p<.05				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1= NNN																				
2= NRN													*	*	*					
3= NDN																*				
4= DRN						*	*													
5= RDN																				

NB.INCORRECT DIFFERENT SEQUENCES (NIS)

AGE	5-6 Y.O.					9-10 Y.O.					14-15 Y.O.					ADULTS				
	NS					NS					F(4,93)=3.3 p<.01					NS				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1= NNN																				
2= NRN																				
3= NDN																				
4= DRN																				
5= RDN													*	*						

NB SEQUENCES DIFFERENT 2 PREVIOUS (NSD2)

AGE	5-6 Y.O.					9-10 Y.O.					14-15 Y.O.					ADULTS				
	NS					F(4,86)=5.5 p<.0005					F(4,93)=6.9 p<.0001					F(4,95)=3.1 p<.02				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
1= NNN																		*		*
2= NRN											*		*	*	*					
3= NDN						*														
4= DRN						*	*						*							
5= RDN																				

TABLE 1.51 : %CS, %DS, NCS, NIS, NSD2: - ANOVA (pre-training) and Newman-Keuls test for each age group, in the third session.

(*) indicates a significant difference with P<.05.

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SEQUENCES UNCERTAINTY (U(S))

AGE	5-6 Y.O.	9-10 Y.O.	14-15 Y.O.	ADULTS
	NS	F(4,86)=4.2 p<.004	F(4,93)=5.4 p<.0005	NS
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1= NNN	1	1	1	1
2= NRN	2	2	2* * * *	2
3= NDN	3	3	3	3
4= DRN	4	4* *	4	4
5= RDN	5	5	5	5

CORRECT SEQUENCES UNCERTAINTY (U(CS))

AGE	5-6 Y.O.	9-10 Y.O.	14-15 Y.O.	ADULTS
	NS	F(4,86)=4.7 p<.002	F(4,93)=5.7 p<.0004	NS
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1= NNN	1	1	1	1
2= NRN	2	2	2* * * *	2
3= NDN	3	3	3	3
4= DRN	4	4* *	4	4
5= RDN	5	5	5	5

INCORRECT SEQUENCES UNCERTAINTY (U(IS))

AGE	5-6 Y.O.	9-10 Y.O.	14-15 Y.O.	ADULTS
	NS	NS	F(4,93)=2.5 p<.04	NS
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1= NNN	1	1	1	1
2= NRN	2	2	2	2
3= NDN	3	3	3	3
4= DRN	4	4	4	4
5= RDN	5	5	5 *	5

MEAN REALIZATION TIME (MTR)

AGE	5-6 Y.O.	9-10 Y.O.	14-15 Y.O.	ADULTS
	NS	NS	NS	F(4,95)=3.5 p<.01
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1= NNN	1	1	1	1
2= NRN	2	2	2	2
3= NDN	3	3	3	3
4= DRN	4	4	4	4* * * *
5= RDN	5	5	5	5

MEAN LATENCY TIME (MTL)

AGE	5-6 Y.O.	9-10 Y.O.	14-15 Y.O.	ADULTS
	NS	NS	NS	NS
	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5	1 2 3 4 5
1= NNN	1	1	1	1
2= NRN	2	2	2	2
3= NDN	3	3	3	3
4= DRN	4	4	4	4
5= RDN	5	5	5	5

TABLE 1.52 : U(S), U(CS), U(IS), MTR, MTL - ANOVA (pre-training) and Newman-Keuls test for each age group, in the third session.
(*) indicates a significant difference with P<.05.

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% CORRECT SEQUENCES (%CS)

SESSIONS	N				N				N			
	F.(3,69)=5.48				F.(3,69)=2.27				F.(3,69)=.93			
	p<0.0019				NS				NS			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.	*											
3= 14-15 Y.O.	*											
4= ADULTS	*											

SESSIONS	N				R				N			
	F.(3,68)=6.97				F.(3,68)=3.90				F.(3,68)=5.92			
	p<0.0004				p<0.0123				p<0.0012			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.	*								*			
3= 14-15 Y.O.	*				*				*			
4= ADULTS	*				*				*			

SESSIONS	N				D				N			
	F.(3,70)=4.53				F.(3,70)=11.5				F.(3,70)=4.91			
	p<0.0058				p<.0000				p<.0037			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.			*		*				*			
3= 14-15 Y.O.	*				*				*			
4= ADULTS	*				*				*			

SESSIONS	D				R				N			
	F.(3,67)=5.08				F.(3,67)=7.44				F.(3,67)=1.48			
	p<0.0031				p<0.0002				NS			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.	*											
3= 14-15 Y.O.	*				*							
4= ADULTS	*				*							

SESSIONS	R				D				N			
	F.(3,70)=7.96				F.(3,70)=6.42				F.(3,70)=9.6			
	p<0.0001				p<0.0007				p<.0000			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.		*										
2= 9-10 Y.O.					*				*			
3= 14-15 Y.O.		*			*				*			
4= ADULTS		*			*				*			

SESSIONS	GN				R				D			
	F.(3,215)=15.62				F.(3,70)=7.96				F.(3,70)=5.09			
	p<.0000				p<.0001				p<.003			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.						*						
2= 9-10 Y.O.	*								*			
3= 14-15 Y.O.	*					*			*			
4= ADULTS	*					*			*			

<u>TABLE 1.53</u> : %CS : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

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SESSIONS	N				N				N			
	F.(3,69)=.35 NS				F.(3,69)=.76 NS				F.(3,69)=.81 NS			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.	*						*				*	
3= 14-15 Y.O.	*						*					*
4= ADULTS	*						*				*	

SESSIONS	N				R				N			
	F.(3,68)=.24 NS				F.(3,68)=1.81 NS				F.(3,68)=1.87 NS			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.	*								*			
3= 14-15 Y.O.	*	*							*	*		
4= ADULTS	*	*							*	*		

SESSIONS	N				D				N			
	F.(3,70)=1.84 NS				F.(3,70)=22 p<.0000				F.(3,70)=3.74 p<.014			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.												
2= 9-10 Y.O.			*		*				*			
3= 14-15 Y.O.	*				*	*			*			
4= ADULTS	*				*	*			*			

SESSIONS	D				R				N			
	F.(3,67)=7.42 p<0.0002				F.(3,67)=6.16 p<0.009				F.(3,67)=3.26 p<.026			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.							*					
2= 9-10 Y.O.	*						*		*			
3= 14-15 Y.O.	*				*				*	*		
4= ADULTS	*				*						*	

SESSIONS	R				D				N			
	F.(3,70)=8 p<0.0001				F.(3,70)=4.39 p<0.0069				F.(3,70)=1.52 NS			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.		*										
2= 9-10 Y.O.	*				*				*			
3= 14-15 Y.O.		*			*				*			
4= ADULTS		*			*				*			

SESSIONS	GN				R				D			
	F.(3,215)=1.67 NS				F.(3,70)=8.003 p<.0001				F.(3,70)=7.42 p<.0002			
	1	2	3	4	1	2	3	4	1	2	3	4
1= 5-6 Y.O.						*						
2= 9-10 Y.O.									*			
3= 14-15 Y.O.						*			*			
4= ADULTS						*			*			

TABLE 1.54 : %DS : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

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NB. CORRECT DIFFERENT SEQUENCES (NCS)

SESSIONS	N					N					N				
	F.(3,69)=.40					F.(3,69)=1.56					F.(3,69)=1.01				
	NS					NS					NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3					3				
4= ADULTS	4					4					4				

SESSIONS	N					R					N				
	F.(3,68)=.12					F.(3,68)=.97					F.(3,68)=2.31				
	NS					NS					NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3					3				
4= ADULTS	4					4					4				

SESSIONS	N					D					N				
	F.(3,70)=5.36					F.(3,70)=25.99					F.(3,70)=5.58				
	p<.0022					p<.0000					p<.0017				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2	*				2				
3= 14-15 Y.O.	3	*				3	*	*			3	*			
4= ADULTS	4	*				4	*	*			4	*			

SESSIONS	D					R					N				
	F.(3,67)=9.28					F.(3,67)=6.38					F.(3,67)=2.52				
	p<0.0000					p<0.0007					p<.065				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3		*			3				
4= ADULTS	4	*				4		*			4				

SESSIONS	R					D					N				
	F.(3,70)=5.82					F.(3,70)=4.77					F.(3,70)=2.02				
	p<0.0013					p<0.0044					NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1		*			1					1				
2= 9-10 Y.O.	2					2	*				2				
3= 14-15 Y.O.	3		*			3	*				3				
4= ADULTS	4		*			4	*				4				

SESSIONS	GN					R					D				
	F.(3,215)=3.23					F.(3,70)=5.82					F.(3,70)=9.29				
	p<.02					p<.001					p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2					2					2	*			
3= 14-15 Y.O.	3	*				3		*			3	*			
4= ADULTS	4	*				4		*			4	*			

TABLE 1.55 : NCS : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

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NB. INCORRECT DIFFERENT SEQUENCES (NIS)

SESSIONS	N					N					N				
	F.(3,69)=5.36 p<.0022					F.(3,69)=3.19 p<.028					F.(3,69)=1.57 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2				
3= 14-15 Y.O.	3	*				3	*				3				
4= ADULTS	4	*				4	*				4				

SESSIONS	N					R					N				
	F.(3,68)=6.66 p<.0005					F.(3,68)=3.07 p<.033					F.(3,68)=6.22 p<.0008				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4	*				4					4	*			

SESSIONS	N					D					N				
	F.(3,70)=1.52 NS					F.(3,70)=5.68 p<.0015					F.(3,70)=4.45 p<.0063				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2	*				2				
3= 14-15 Y.O.	3	*				3	*	*			3	*			
4= ADULTS	4	*				4	*	*			4	*			

SESSIONS	D					R					N				
	F.(3,67)=2.97 p<0.037					F.(3,67)=7.19 p<0.0003					F.(3,67)=3.17 p<.0296				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2			*		2				
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4	*				4			*		4				

SESSIONS	R					D					N				
	F.(3,70)=7.49 p<0.0002					F.(3,70)=3.58 p<0.017					F.(3,70)=6.17 p<.0009				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4		*			4	*				4	*			

SESSIONS	GN					R					D				
	F.(3,215)=11.69 p<.0000					F.(3,70)=7.49 p<0.0002					F.(3,70)=2.97 p<.037				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2	*				2					2				
3= 14-15 Y.O.	3	*				3	*				3				
4= ADULTS	4	*				4		*			4				

TABLE 1.56 : NIS : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

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NB. SEQ. DIFF. 2 PREV. (NSD2)

SESSIONS	N					N					N				
	F.(3,69)=.81 NS					F.(3,69)=3.19 p<.028					F.(3,69)=2.95 p<.038				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2				
3= 14-15 Y.O.	3	*				3	*				3		*		
4= ADULTS	4	*				4	*				4				

SESSIONS	N					R					N				
	F.(3,68)=.35 NS					F.(3,68)=.55 NS					F.(3,68)=2.43 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4	*				4					4	*			

SESSIONS	N					D					N				
	F.(3,70)=5.39 p<.0021					F.(3,70)=44.16 p<.0000					F.(3,70)=7.60 p<.0002				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2	*				2				
3= 14-15 Y.O.	3	*				3	*	*			3	*	*		
4= ADULTS	4	*				4	*	*			4	*			

SESSIONS	D					R					N				
	F.(3,67)=18.37 p<0.0000					F.(3,67)=3.66 p<0.016					F.(3,67)=3.07 p<.033				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2	*				2			*		2	*			
3= 14-15 Y.O.	3	*				3		*			3	*			
4= ADULTS	4	*				4		*			4				

SESSIONS	R					D					N				
	F.(3,70)=5.04 p<0.0032					F.(3,70)=11.09 p<.0000					F.(3,70)=4.57 p<.0056				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1				*	1					1				
2= 9-10 Y.O.	2				*	2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4		*			4	*				4	*			

SESSIONS	GN					R					D				
	F.(3,215)=4.04 p<.008					F.(3,70)=5.04 p<0.0032					F.(3,70)=18.37 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2	*			
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4					4	*	*			4	*			

TABLE 1.57 : NSD2 : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

SESSIONS	N					N					N				
	F.(3,69)=.28 NS					F.(3,69)=.37 NS					F.(3,69)=.38 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3					3				
4= ADULTS	4					4					4				

SESSIONS	N					R					N				
	F.(3,68)=.63 NS					F.(3,68)=1.99 NS					F.(3,68)=2.35 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3					3				
4= ADULTS	4					4					4				

SESSIONS	N					D					N				
	F.(3,70)=1.71 NS					F.(3,70)=15.78 p<.0000					F.(3,70)=3.03 p<.034				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2	*				2				
3= 14-15 Y.O.	3					3	*	*			3				
4= ADULTS	4					4	*	*			4	*			

SESSIONS	D					R					N				
	F.(3,67)=4.69 p<0.0048					F.(3,67)=9.99 p<0.0000					F.(3,67)=2.33 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2	*				2					2				
3= 14-15 Y.O.	3	*				3		*			3				
4= ADULTS	4	*				4		*			4				

SESSIONS	R					D					N				
	F.(3,70)=8.62 p<0.0001					F.(3,70)=2.33 NS					F.(3,70)=.70 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1		*			1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3		*			3					3				
4= ADULTS	4		*			4					4				

SESSIONS	GN					R					D				
	F.(3,215)= NS					F.(3,70)=8.62 p<0.0001					F.(3,70)=4.69 p<.0049				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2					2					2	*			
3= 14-15 Y.O.	3					3		*			3	*			
4= ADULTS	4					4		*			4	*			

TABLE 1.58 : U(S) : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

SESSIONS	N					N					N				
	F.(3,69)=.41 NS					F.(3,69)=1.45 NS					F.(3,69)=1.21 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3					3				
4= ADULTS	4					4					4				

SESSIONS	N					R					N				
	F.(3,68)=.08 NS					F.(3,68)=1.36 NS					F.(3,68)=1.88 NS				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3					3				
4= ADULTS	4					4					4				

SESSIONS	N					D					N				
	F.(3,70)=4.57 p<.0055					F.(3,70)=29.63 p<.0000					F.(3,70)=5.77 p<.034				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2	*				2				
3= 14-15 Y.O.	3	*				3	*	*			3	*			
4= ADULTS	4	*				4	*	*			4	*			

SESSIONS	D					R					N				
	F.(3,67)=11.12 p<0.0000					F.(3,67)=8.05 p<0.0001					F.(3,67)=3.54 p<.019				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3		*			3	*			
4= ADULTS	4	*				4		*			4				

SESSIONS	R					D					N				
	F.(3,70)=6.47 p<0.0006					F.(3,70)=6.5 p<.0006					F.(3,70)=3.26 p<.023				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1		*			1					1				
2= 9-10 Y.O.	2					2	*				2	*			
3= 14-15 Y.O.	3		*			3	*				3	*			
4= ADULTS	4		*			4	*				4	*			

SESSIONS	GN					R					D				
	F.(3,215)=2.88 p<.037					F.(3,70)=6.42 p<0.0006					F.(3,70)=11.12 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1		*			1				
2= 9-10 Y.O.	2					2					2	*			
3= 14-15 Y.O.	3	*				3		*			3	*			
4= ADULTS	4					4		*			4	*			

TABLE 1.59 : U(CS) : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

SESSIONS	N					N					N				
	F.(3,69)=3.39 p<.022					F.(3,69)=3.8 p<.013					F.(3,69)=2.73 p<.05				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3				
4= ADULTS	4	*				4	*				4	*			

SESSIONS	N					R					N				
	F.(3,68)=3.26 p<.026					F.(3,68)=2.42 NS					F.(3,68)=6.36 p<.0007				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4	*				4					4	*			

SESSIONS	N					D					N				
	F.(3,70)=.74 NS					F.(3,70)=4.65 p<.0051					F.(3,70)=3.47 p<.020				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2					2					2				
3= 14-15 Y.O.	3					3	*				3	*			
4= ADULTS	4					4	*				4				

SESSIONS	D					R					N				
	F.(3,67)=3.99 p<0.0112					F.(3,67)=8.60 p<0.0001					F.(3,67)=8.12 p<.0001				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1			*		1				
2= 9-10 Y.O.	2					2			*		2				
3= 14-15 Y.O.	3	*	*			3					3	*	*		
4= ADULTS	4	*	*			4			*		4	*	*		

SESSIONS	R					D					N				
	F.(3,70)=7.37 p<0.0002					F.(3,70)=3.14 p<.0303					F.(3,70)=4.98 p<.0034				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3					3	*			
4= ADULTS	4	*	*			4					4	*			

SESSIONS	GN					R					D				
	F.(3,215)=5.73 p<.0009					F.(3,70)=7.38 p<0.0002					F.(3,70)=3.99 p<.01				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2				
3= 14-15 Y.O.	3	*				3	*				3	*	*		
4= ADULTS	4	*				4	*	*			4	*	*		

TABLE 1.60 : U(IS) : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

MEAN REALIZATION TIME

SESSIONS	N					N					N				
	F.(3,69)=4.18 p<.0088					F.(3,69)=10.78 p<.0000					F.(3,69)=2.88 p<.042				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3		*		
4= ADULTS	4	*				4	*				4	*			

SESSIONS	N					R					N				
	F.(3,68)=14.52 p<.0000					F.(3,68)=2.04 NS					F.(3,68)=27.55 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*	*			3					3	*	*		
4= ADULTS	4	*	*			4					4	*	*		

SESSIONS	N					D					N				
	F.(3,70)=14.09 p<.0000					F.(3,70)=9.39 p<.0000					F.(3,70)=13.86 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4	*				4	*				4	*			

SESSIONS	D					R					N				
	F.(3,67)=12.36 p<0.0000					F.(3,67)=1.96 NS					F.(3,67)=2.74 p<.0497				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1			*		1				
2= 9-10 Y.O.	2	*				2			*		2	*			
3= 14-15 Y.O.	3	*	*			3		*			3	*	*		
4= ADULTS	4	*	*			4			*		4			*	

SESSIONS	R					D					N				
	F.(3,70)=1.87 NS					F.(3,70)=11 26 p<.0000					F.(3,70)=13.80 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1		*			1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4	*	*			4	*				4	*			

SESSIONS	GN					R					D				
	F.(3,215)=26.17 p<.0000					F.(3,70)= NS					F.(3,70)=12.37 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*	*			3					3	*	*		
4= ADULTS	4	*	*			4					4	*	*		

TABLE 1.61 : MTR : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

SESSIONS	N					N					N				
	F.(3,69)=8.34 p<.0001					F.(3,69)=8.44 p<.0001					F.(3,69)=13.42 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4	*				4	*				4	*			

SESSIONS	N					R					N				
	F.(3,68)=14.86 p<.0000					F.(3,68)=11.5 NS					F.(3,68)=17.34 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4	*				4	*				4	*			

SESSIONS	N					D					N				
	F.(3,70)=4.55 p<.0056					F.(3,70)=16.18 p<.0000					F.(3,70)=7.73 p<.0002				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4	*				4	*				4	*			

SESSIONS	D					R					N				
	F.(3,67)=18.62 p<0.0000					F.(3,67)=13.14 p<0.0000					F.(3,67)=5.15 p<.0029				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1			*		1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*	*			3	*	*			3	*			
4= ADULTS	4	*	*			4	*				4	*			

SESSIONS	R					D					N				
	F.(3,70)=1.32 NS					F.(3,70)=3.52 p<.0193					F.(3,70)=5.19 p<.0027				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1		*			1					1				
2= 9-10 Y.O.	2	*				2	*				2	*			
3= 14-15 Y.O.	3	*				3	*				3	*			
4= ADULTS	4	*	*			4	*				4	*			

SESSIONS	GN					R					D				
	F.(3,215)=23.76 p<.0000					F.(3,70)= NS					F.(3,70)=18.62 p<.0000				
		1	2	3	4		1	2	3	4		1	2	3	4
1= 5-6 Y.O.	1					1					1				
2= 9-10 Y.O.	2	*				2					2	*			
3= 14-15 Y.O.	3	*				3					3	*	*		
4= ADULTS	4	*				4					4	*	*		

TABLE 1.62 : MTL : ANOVA (age) and Newman-Keuls test for each experimental group, in each session, and for each matrix type, in the first session.

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	N global	N	N	N	C	N
%C.S.	87.4545 (11.6649)	86.0000 (9.2952)	93.4545 (5.1452)	95.4545 (2.3817)	82.7273 (15.7519)	98.1818 (1.8878)
%D.S.	53.3636 (22.4532)	54.7273 (21.9868)	58.7273 (30.2029)	62.7273 (27.6300)	47.6364 (27.6813)	78.9091 (24.6311)
N.C.S.	6.0455 (3.5251)	4.4545 (2.6216)	5.1818 (3.4876)	5.3636 (4.8636)	10.1818 (3.9955)	3.1818 (3.1880)
N.I.S.	3.0000 (1.9272)	3.5455 (1.8635)	2.5455 (1.8091)	1.8182 (.9816)	6.0909 (4.5707)	.7273 (.6467)
U(S)	1.9932 (.8921)	1.8364 (.8721)	1.6273 (1.2020)	1.5718 (1.1623)	2.7891 (1.2340)	.8273 (.9152)
U(C.S.)	1.5195 (.8848)	1.2509 (.7840)	1.3282 (1.0545)	1.3336 (1.1937)	2.1591 (1.0969)	.7218 (.9161)
U(I.S.)	1.2009 (.8753)	1.5309 (.7625)	1.0491 (.9429)	.7836 (.6710)	2.1100 (1.1796)	.0827 (.2744)
N.S.D2	13.8636 (9.3008)	10.6364 (5.3334)	10.7273 (9.5508)	13.4545 (13.1861)	18.1818 (11.3209)	8.0000 (11.4018)
$N.S.D_{10}$	7.6818 (5.3308)	5.5455 (3.3871)	6.4545 (4.9873)	7.2727 (8.2957)	13.0909 (7.0207)	4.0909 (5.3189)
N.S.C.	.7273 (10.320)	.3636 (.6742)	1.3636 (3.2641)	.9091 (1.4460)	23.1818 (15.1183)	14.0909 (21.3703)

TABLE 2.1 : For each index, mean and standard deviation in N global and in each session of the group NNNCN, for the adults of the T population.

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	N global	N	N	N	C	N
%C.S.	84.3871 (13.5786)	84.8000 (13.0887)	94.2667 (6.9227)	92.0000 (9.1652)	89.3333 (13.5365)	96.2667 (7.6295)
%D.S.	52.9677 (22.0477)	47.0667 (23.6748)	50.2667 (23.6506)	47.8667 (23.7663)	57.8667 (28.8391)	61.2000 (26.9688)
N.C.S.	6.0000 (3.3466)	7.4000 (3.6016)	7.1333 (3.7391)	6.8000 (3.6884)	10.2000 (4.4433)	6.8667 (3.9976)
N.I.S.	3.7742 (2.7774)	3.6667 (2.6904)	1.8667 (2.5598)	2.4000 (2.6939)	3.1333 (3.7200)	1.2000 (2.1112)
U(S)	2.1500 (.9954)	2.4193 (1.0846)	2.1073 (.9883)	2.1860 (1.0398)	2.2900 (1.3272)	1.7640 (1.2125)
U(C.S.)	1.5823 (.9181)	1.9333 (.9480)	1.8793 (.9123)	1.8887 (.9507)	1.9520 (1.1417)	1.6333 (1.0927)
U(I.S.)	1.3868 (.8816)	1.3320 (.8873)	.6807 (.9329)	.9280 (.9571)	1.1427 (1.1778)	.4280 (.8438)
N.S.D2	14.4839 (8.7020)	17.4000 (8.2184)	19.6000 (10.0768)	19.0000 (11.7047)	17.9333 (11.5910)	16.6667 (11.0432)
$N.S.D_{10}$	8.6774 (5.2178)	10.5333 (5.5532)	9.7333 (5.9578)	10.8000 (7.6737)	12.6000 (6.8848)	9.6667 (6.8834)
N.S.C.	1.0000 (1.3904)	1.4667 (1.5523)	1.2000 (1.5675)	1.1333 (1.5976)	23.6667 (17.7911)	4.4000 (8.8946)

TABLE 2.2 : For each index, mean and standard deviation in N global and in each session of the group NNNCN, for the adolescents of the T population.

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	N	D	D_{10}	C	N
%C.S.	88.9091 (13.9532)	94.1818 (5.5465)	93.6364 (10.8745)	94.9091 (10.4063)	98.5455 (3.5879)
%D.S.	52.0000 (23.8998)	23.6364 (11.3073)	14.7273 (3.2586)	63.6364 (14.7046)	66.5455 (34.0481)
N.C.S.	7.6364 (3.6952)	11.2727 (4.3380)	14.5455 (3.4165)	10.4545 (2.4643)	6.5455 (6.0723)
N.I.S.	2.4545 (1.9164)	2.1818 (1.9909)	2.0909 (2.9480)	1.6364 (2.9757)	.3636 (.6742)
U(S)	2.1500 (.9256)	3.1827 (.7268)	3.7336 (.3031)	2.0545 (.6965)	1.4882 (1.4374)
U(C.S.)	1.7882 (.9331)	2.9655 (.8211)	3.5545 (.4267)	1.8600 (.5012)	1.4236 (1.4305)
U(I.S.)	.8709 (.8876)	.9364 (.9627)	.7909 (1.0445)	.5900 (1.1081)	.0900 (.2985)
N.S.D2	17.0909 (11.4145)	32.9091 (10.3871)	39.4545 (7.3806)	14.2727 (4.0765)	14.7273 (15.6083)
N.S.D_{10}	9.8182 (6.1777)	16.8182 (7.5474)	23.3636 (7.3386)	11.7273 (3.1966)	9.2727 (9.8802)
N.S.C.	1.0909 (1.2210)	2.5455 (3.3276)	4.6364 (3.0091)	32.9091 (11.4931)	19.0000 (23.0521)

TABLE 2.3 : For each index, mean and standard deviation in each session of the group $NDD_{10}CN$, for the adults of the T population.

261

	N	D	D_{10}	C	N
%C.S.	84.0000 (14.4407)	92.0000 (10.3795)	94.1250 (10.9415)	91.0000 (13.1250)	98.2500 (3.7148)
%D.S.	58.5000 (19.5346)	23.6250 (10.7634)	18.8750 (8.1312)	54.6250 (27.3810)	67.0000 (28.3596)
N.C.S.	4.6875 (2.5487)	11.3125 (4.3469)	14.4375 (3.1826)	10.3125 (3.3009)	5.2500 (3.2965)
N.I.S.	3.8750 (2.9411)	3.2500 (3.4928)	2.2500 (3.3764)	3.0000 (3.9665)	.6875 (1.4009)
U(S)	1.8975 (.8620)	3.2238 (.8446)	3.6713 (.3304)	2.3769 (1.2056)	1.3434 (1.0023)
U(C.S.)	1.2531 (.7800)	2.9550 (.7475)	3.4800 (.4343)	2.1069 (.9644)	1.2506 (1.0332)
U(I.S.)	1.4381 (.9022)	1.1412 (1.1927)	.7669 (1.0951)	.9719 (1.2891)	.2263 (.6388)
$N.S.D_2$	11.7500 (8.4814)	32.2500 (7.6898)	38.4375 (6.8114)	19.5000 (10.2892)	14.3750 (15.2398)
$N.S.D_{10}$	6.9375 (4.3584)	16.8125 (7.5474)	24.6250 (5.8523)	12.6875 (5.5464)	6.5625 (4.9121)
N.S.C.	.5625 (1.0935)	2.9375 (3.7143)	4.8750 (4.4253)	26.3750 (16.0452)	8.5000 (15.9625)

TABLE 2.4 : For each index, mean and standard deviation in each session of the group $NDD_{10}CN$, for the adolescents of the T population.

2 6 2

	N global	N	N	N
%C.S.	93.0244 (7.1431)	94.2857 (4.7026)	93.3333 (8.6101)	91.5238 (21.1934)
%D.S.	58.0000 (26.1763)	61.2381 (26.1494)	62.4762 (27.4729)	63.7143 (28.4976)
N.C.S.	6.9512 (4.2717)	6.7143 (4.4849)	6.0000 (4.4045)	5.0952 (4.0113)
N.I.S.	2.3171 (1.9930)	2.2381 (1.8413)	2.0000 (1.7321)	1.6190 (1.6272)
U(S)	1.1954 (1.1600)	1.7971 (1.1625)	1.6710 (1.1679)	1.5338 (1.1320)
U(C.S.)	1.6351 (1.0687)	1.5290 (1.0956)	1.4205 (1.0714)	1.2362 (1.1421)
U(I.S.)	.9141 (.9432)	.8871 (.9642)	.7852 (.7794)	.5357 (.7165)
$N.S.D_2$	15.4390 (10.6491)	15.3333 (11.6161)	14.0952 (10.5967)	32.1579 (15.5108)

TABLE 2.5 : For each index, mean and standard deviation in N global and in each session of the group NNN, for the adults of the G population.

263

	N global	N	N	N
%C.S.	94.0556 (5.3769)	93.0588 (6.4077)	95.2941 (5.4745)	96.2353 (4.4092)
%D.S.	52.3333 (26.2319)	52.7059 (27.8293)	54.5882 (25.9303)	54.7059 (26.8416)
N.C.S.	7.3056 (4.5783)	6.4118 (3.9220)	5.7647 (3.4556)	5.9412 (3.0510)
N.I.S.	2.2778 (2.0648)	2.6471 (2.3964)	1.8235 (2.1574)	1.4706 (1.4194)
U(S)	2.0603 (1.1547)	2.0100 (1.2218)	1.8188 (1.0889)	1.7841 (.9634)
U(C.S.)	1.0814 (1.1077)	1.7112 (1.1091)	1.6100 (1.0085)	1.6094 (.9371)
U(I.S.)	.8969 (.9461)	1.0524 (1.0345)	.7306 (.9268)	.4641 (.7236)
$N.S.D_2$	19.5000 (12.0250)	18.3529 (12.2574)	19.7059 (12.2870)	20.4118 (12.0730)

TABLE 2.6 : For each index, mean and standard deviation in N global and in each session of the group NNN, for the adolescents of the G population.

264

	N	D.
%C.S.	91.7000 (8.9742)	96.9000 (3.6978)
%D.S.	54.6000 (26.4384)	21.8000 (11.1996)
N.C.S.	7.2000 (4.1371)	13.5500 (4.4660)
N.I.S.	2.4000 (2.1861)	1.4000 (1.6351)
U(S)	2.0395 (1.1742)	3.3845 (.7959)
U(C.S.)	1.7465 (1.0563)	3.2815 (.7635)
U(I.S.)	.9425 (.9448)	.5025 (.8441)
N.S.D_2	15.5500 (9.8327)	37.9500 (7.2291)

TABLE 2.7 : For each index, mean and standard deviation in the first two sessions of the group NDN, for the adults of the G population.

2 C5

	N	D
%C.S.	94.9474 (4.2357)	96.7368 (2.7657)
%D.S.	52.0000 (25.4820)	20.5263 (6.3890)
N.C.S.	8.1053 (5.0651)	13.6316 (2.5865)
N.I.S.	1.9474 (1.7151)	1.6316 (1.3829)
U(S)	2.1053 (1.1230)	3.4542 (.3091)
U(C.S.)	1.8821 (1.1306)	3.3311 (.3287)
U(I.S.)	.7579 (.8638)	.7274 (.7329)
$N.S.D_2$	20.5263 (12.0525)	38.4211 (5.8435)

TABLE 2.8 : For each index, mean and standard deviation in the first two sessions of the group NDN, for the adolescents of the G population.

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%C.S.

	N	N	N	C	N
N		-3.66	-3.71	.53	-4.26
N	**		-1.29	1.91	-2.61
N	**	N.S.		2.47	-2.89
C	N.S.	N.S.	*		-3.77
N	**	*	*	**	

% D.S.

	-.53	-1.55	.67	-3.17
N.S.		-.40	.92	-1.64
N.S.	N.S.		1.41	-1.86
N.S.	N.S.	N.S.		-3.38
**	N.S.	N.S.	**	

N.C.S.

	-.73	-.82	-6.55	-1.57
N.S.		-.14	-4.5	1.4
N.S.	N.S.		-3.29	1.57
***	***	**		5.73
N.S.	N.S.	N.S.	***	

N.I.S.

	1.66	3.41	-1.57	4.95
N.S.		1.62	-2.12	2.96
**	N.S.		-2.75	3.18
N.S.	N.S.	*		3.99
***	*	**	**	

U(S)

	.82	1.15	-2.18	3.65
N.S.		.16	-2.31	1.7
N.S.	N.S.		-2.55	1.98
*	*	*		4.95
**	N.S.	N.S.	***	

U(C.S.)

	-.30	-.38	-2.93	2.03
N.S.		-.01	-2.23	1.36
N.S.	N.S.		-2.18	1.68
*	*	N.S.		4.10
N.S.	N.S.	N.S.	**	

U(I.S.)

	1.91	2.86	-1.25	5.36
N.S.		1.10	-2.00	2.98
*	N.S.		-2.70	2.84
N.S.	N.S.	*		6.07
***	*	*	***	

N.S.D_2

	-.03	-.70	-2.2	.83
N.S.		-.88	-2.39	.62
N.S.	N.S.		-1.82	1.41
N.S.	*	N.S.		2.67
N.S.	N.S.	N.S.	*	

N.S.D_{10}

	-.69	-.83	-4.19	1.07
N.S.		-.42	-3.50	1.06
N.S.	N.S.		-2.92	1.40
**	**	*		4.92
N.S.	N.S.	N.S.	***	

N.S.C.

	-.97	-1.26	-4.94	-2.10
N.S.		.51	-4.91	-1.89
N.S.	N.S.		-4.7	-2
***	***	***	-	1.45
N.S.	N.S.	N.S.	N.S.	

TABLE 2.9 : For each index, Student-T-tests for related samples, for the 5 sessions of the experimental group NNNCN, among the adults.

%C.S.

	N	N	N	C	N
N		-3.61	-2.62	-1.16	-3.69
N	**		1.64	2.23	-1.81
N	*	N.S.		1.02	-2.8
C	N.S.	*	N.S.		-3.2
N	**	N.S.	*	**	

% D.S.

	-.78	-.14	-1.18	-1.78
N.S.		.45	-.81	-1.45
N.S.	N.S.		-1.16	-2
N.S.	N.S.	N.S.		-.49
N.S.	N.S.	N.S.	N.S.	

N.C.S.

	.40	.66	-1.82	.42
N.S.		.48	-2.13	.23
N.S.	N.S.		-2.6	-.06
N.S.	*	*		3.67
N.S.	N.S.	N.S.	**	

N.I.S.

	2.71	1.63	.53	3.65
*		-1.12	-2.28	2.2
N.S.	N.S.		-.89	3.06
N.S.	*	N.S.		3.28
**	*	**	**	

U(S)

	2.16	.91	.31	1.82
*		-.39	-.49	1.10
N.S.	N.S.		-.27	1.44
N.S.	N.S.	N.S.		1.84
N.S.	N.S.	N.S.	N.S.	

U(C.S.)

	.32	.20	-.05	.87
N.S.		-.05	-.20	.81
N.S.	N.S.		-.18	.94
N.S.	N.S.	N.S.		1.25
N.S.	N.S.	N.S.	N.S.	

U(I.S.)

	2.71	1.37	.63	3.91
*		-1.07	-2.21	1.64
N.S.	N.S.		-.67	2.84
N.S.	*	N.S.		3.32
**	N.S.	*	**	

N.S.D_2

	-1.26	-.75	-.14	.22
N.S.		.31	.47	.83
N.S.	N.S.		.26	.72
N.S.	N.S.	N.S.		.48
N.S.	N.S.	N.S.	N.S.	

N.S.D_{10}

	.94	-.21	-.86	.38
N.S.		-.75	-1.2	.03
N.S.	N.S.		-.71	.49
N.S.	N.S.	N.S.		1.39
N.S.	N.S.	N.S.	N.S.	

N.S.C.

	.56	.75	-4.90	-1.38
N.S.		.15	-4.84	-1.34
N.S.	N.S.		-4.89	-1.52
***	***	***	-	4.65
N.S.	N.S.	N.S.	***	

TABLE 2 10 : For each index, Student-T-tests for related samples, for the 5 sessions of the experimental group NNNCN, among the 14-15 y.o.

% C.S.

	N	D	D10	C	N
N		- 1.6	-1.61	-4.36	-2.88
D	N.S.		.25	-.32	-2.74
D 10	N.S.	N.S.		-.63	-1.6
C	•••	N.S.	N.S.		-1.55
N	•	•	N.S.	N.S.	

% D.S.

	4.25	5.20	-1.62	-1.54
••		3	-6.92	-4.37
•••	•		- 8.52	-5.14
N.S.	•••	•••		-.24
N.S.	•••	•••	N.S.	

N.C.S.

	-3.77	-4.69	-2.23	.78
••		-2.26	.67	2.79
•••	•		4.31	4.43
•	N.S.	••		2.16
N.S.	•	•••	N.S.	

N.I.S.

	.56	.61	1.4	3.82
N.S.		.21	.86	2.89
N.S.	N.S.		1.05	1.97
N.S.	N.S.	N.S.		1.55
••	•	N.S.	N.S.	

U(S)

	-4.21	-5.27	.34	1.8
••		-2.77	4.53	3.97
•••	•		7.03	4.97
N.S.	•••	•••		1.11
N.S.	••	•••	N.S.	

U(C.S.)

	-4.78	-5.64	-.24	1.11
•••		-2.48	4.72	3.89
•••	•		7.60	5.08
N.S.	•••	•••		.94
N.S.	••	•••	N.S.	

U(I.S.)

	-.27	.31	.92	3.01
N.S.		1.06	1.3	3.07
N.S.	N.S.		.92	2.48
N.S.	N.S.	N.S.		1.76
•	•	•	N.S.	

N.S.D_2

	[illegible]	-5.42	.86	.70
•••		-3.95	6.82	5.04
•••	••		10.95	6.28
N.S.	•••	•••		-.10
N.S.	•••	•••	N.S.	

N.S.D_{10}

	-3.37	-6.01	-1.02	-.21
••		-3.66	2.49	2.70
•••	••		5.74	5.98
N.S.	•	•••		.80
N.S.	•	•••	N.S.	

N.S.C.

	-1.32	-3.67	-9.24	-2.54
N.S.		-1.58	-8.56	-2.32
••	N.S.		-9.27	-2.01
•••	•••	•••	-	1.98
•	•	N.S.	N.S.	

TABLE 2.11 : For each index, Student-T-tests for related samples, for the 5 sessions of the experimental group $NDD_{10}CN$, among the adults.

%C.S.

	N	D	D10	C	N
N		-3.11	-4.06	-3.22	-4.10
D	**		-2.07	.50	-2.86
D10	***	N.S.		1.57	-1.87
C	**	N.S.	N.S.		-2.64
N	***	*	N.S.	*	

%D.S.

	6.68	6.97	.72	-1.18
***		1.47	-4.43	-5.21
***	N.S.		-4.82	-6.58
N.S.	***	***		-1.53
N.S.	***	***	N.S.	

N.C.S.

	-5.89	-9.85	-5.93	-.55
***		-2.4	.78	4.37
***	*		3.75	11.93
***	N.S.	**		6.85
N.S.	***	***	***	

N.I.S

	.95	2.47	1.4	4.74
N.S.		2.24	.28	3.66
*	*		-.92	2.40
N.S.	N.S.	N.S.		2.82
***	**	*	*	

U(S)

	-5.17	-8.12	-1.92	1.94
***		-2.07	-2.57	5.01
***	N.S.		4.18	9.65
N.S.	**	***		3.39
N.S.	***	***	**	

U(C.S.)

	-7.48	-9.94	-3.30	.01
***		-2.37	2.99	4.75
***	*		4.8	9.23
**	**	***		2.94
N.S.	***	***	**	

U(I.S.)

	1.09	2.73	1.6	4.93
N.S.		1.74	.44	3.2
*	N.S.		-.69	2.49
N.S.	N.S.	N.S.		2.89
***	**	*	*	

N.S.D_2

	-6.94	-9.15	-2.73	-.62
***		-3.81	4	5.07
***	**		5.89	7.14
*	***	***		1.26
N.S.	***	***	N.S.	

N.S.D_{10}

	-5.19	-10.2	-4.49	.25
***		-3.9	2	5.08
***	***		7.01	16.18
***	N.S.	***		4.36
N.S.	***	***	***	

N.S.C.

	-2.54	-3.77	-6.35	-1.98
*		-1.45	-5.8	-1.53
**	N.S.		-5.31	-.85
***	***	***		3.85
N.S.	N.S.	N.S.	***	

TABLE 2.12 For each index, Student-T-tests for related samples, for the 5 sessions of the experimental group $NDD_{10}CN$, among the 14-15 y.o.

	N global	N	N .	N	C	N
%C.S.	t=-.86 N.S.	t=.26 N.S.	t=.33 N.S.	t=-1.21 N.S.	t=1.15 N.S.	t=-.81 N.S.
%D.S.	t=-.06 N.S.	t=-.84 N.S.	t=-.80 N.S.	t=-1.47 N.S.	t=.91 N.S.	t=-1.71 N.S.
N.C.S.	t=-.05 N.S.	t=2.3 *	t=1.35 N.S.	t=.86 N.S.	t=.01 N.S.	t=2.52 *
N.I.S.	t=1.13 N.S.	t=.13 N.S.	t=-.75 N.S.	t=.68 N.S.	t=-1.82 N.S.	t=.71 N.S.
U(S)	t=.59 N.S.	t=1.47 N.S.	t=1.12 N.S.	t=1.42 N.S.	t=-.98 N.S.	t=2.15 *
U(C.S.)	t=-.25 N.S.	t=1.95 N.S.	t=1.43 N.S.	t=1.32 N.S.	t=-.46 N.S.	t=2.24 *
U(I.S.)	t=.76 N.S.	t=-.60 N.S.	t=-.99 N.S.	t=.43 N.S.	t=-2.07 *	t=1.3 N.S.
$N.S.D_2$	t=.25 N.S.	t=2.38 *	t=2.27 *	t=1.13 N.S.	t=-.05 N.S.	t=1.35 N.S.
$N.S.D_{10}$	t=.68 N.S.	t=2.63 *	t=1.48 N.S.	t=1.12 N.S.	t=-.18 N.S.	t=2.24 *
N.S.C.	t=.78 N.S.	t=2.2 *	t=-.17 N.S.	t=.37 N.S.	t=.07 N.S.	t=-1.59 N.S.

TABLE 2.13 : Student T-test (age) in N global and in each session of the group NNNCN.

	N	D	D_{10}	C	N
%C.S.	t=-.88 N.S.	t=-.64 N.S.	t=.11 N.S.	t=-.82 N.S.	t=-.21 N.S.
%D.S.	t=.78 N.S.	t=0 N.S.	t=1.6 N.S.	t=-.96 N.S.	t=.04 N.S.
N.C.S.	t=-2.46 *	t=.02 N.S.	t=-.08 N.S.	t=-.12 N.S.	t=-.72 N.S.
N.I.S.	t=1.41 N.S.	t=.91 N.S.	t=.13 N.S.	t=.97 N.S.	t=.71 N.S.
U(S)	t=-.73 N.S.	t=.13 N.S.	t=-.50 N.S.	t=.80 N.S.	t=-.30 N.S.
U(C.S.)	t=-1.62 N.S.	t=-.03 N.S.	t=-.44 N.S.	t=.78 N.S.	t=-.37 N.S.
U(I.S.)	t=1.62 N.S.	t=.47 N.S.	t=-.06 N.S.	t=.80 N.S.	t=.66 N.S.
N.S.D_2	t=-1.4 N.S.	t=-.19 N.S.	t=-.37 N.S.	t=1.59 N.S.	t=-.06 N.S.
N.S.D_{10}	t=-1.42 N.S.	t=0 N.S.	t=.50 N.S.	t=.52 N.S.	t=-.95 N.S.
N.S.C.	t=-1.18 N.S.	t=.28 N.S.	t=.16 N.S.	t=-1.16 N.S.	t=1.40 N.S.

TABLE 2.14 : Student T-test (age) in N global and in each session of the group $NDD_{10}CN$. (* : $p<.05$).

	ANOVA (AGE x MATRIX)		
%C.S.	Factor age :	F(1,52)=.111	N.S.
	Factor Matrix :	F(1,52)=.240	N.S.
	Age x Matrix	F(1,52)=.494	N.S.
%D.S.	Factor age :	F(1,52)=.556	N.S.
	Factor Matrix :	F(1,52)=29.799	p<.0000
	Age x Matrix	F(1,52)=.563	N.S.
N.C.S.	Factor age :	F(1,52)=.776	N.S.
	Factor Matrix :	F(1,52)=20.450	p<.0000
	Age x Matrix	F(1,52)=.730	N.S.
N.I.S.	Factor age :	F(1,52)=.077	N.S.
	Factor Matrix :	F(1,52)=.803	N.S.
	Age x Matrix	F(1,52)=1.385	N.S.
U(S)	Factor age :	F(1,52)=.954	N.S.
	Factor Matrix :	F(1,52)=24.963	p<.0000
	Age x Matrix	F(1,52)=.688	N.S.
U(C.S.)	Factor age :	F(1,52)=1.175	N.S.
	Factor Matrix :	F(1,52)=29.153	p<.0000
	Age x Matrix	F(1,52)=1.311	N.S.
U(I.S.)	Factor age :	F(1,52)=0.74	N.S.
	Factor Matrix :	F(1,52)=621	N.S.
	Age x Matrix	F(1,52)=1.002	N.S.
$N.S.D_2$	Factor age :	F(1,52)=2.290	N.S.
	Factor Matrix :	F(1,52)=39.776	p<.0000
	Age x Matrix	F(1,52)=3.329	N.S.
$N.S.D_{10}$	Factor age :	F(1,52)=.761	N.S.
	Factor Matrix :	F(1,52)=21.412	p<.0000
	Age x Matrix	F(1,52)=.783	N.S.
N.S.C.	Factor age :	F(1,52)=.019	N.S.
	Factor Matrix :	F(1,52)=3.270	N.S.
	Age x Matrix	F(1,52)=.106	N.S.

TABLE 2.15 : For each index, ANOVA (age x matrix) in the second session (matrixes N and D, after N).

	14-15y.o. (df=29)	ADULTS (df=20)
%C.S.	t=.71 N.S.	t=-.32 N.S.
%D.S.	t=4.08 ***	t=3.61 **
N.C.S.	t=-2.86 **	t=-3.63 **
N.I.S.	t=-1.25 N.S.	t=.45 N.S.
U(S)	t=-3.39 **	t=-3.67 **
U(C.S.)	t=-3.6 ***	t=-4.06 ***
U(I.S.).	t=-1.19 N.S.	t=.28 N.S.
N.S.D_2	t=-3.94 ***	t=-5.21 ***
N.S.D_{10}	t=-2.89 **	t=-3.8 ***
N.S.C.	t=-1.68 N.S.	t=-.84 N.S.

TABLE 2.16 : For each index, Student T-test (matrix) in the second session, for each age-group. (** : p<.01; *** : p<.001).

	ANOVA (AGE x PRE-TRAINING)		
%C.S.	Factor age :	$F(1,52)=.116$	N.S.
	Factor Pre-Training :	$F(1,52)=2.658$	N.S.
	Age x Pre-Training :	$F(1,52)=1.999$	N.S.
%D.S.	Factor age :	$F(1,52)=.004$	N.S.
	Factor Pre-Training :	$F(1,52)=.428$	N.S.
	Age x Pre-Training :	$F(1,52)=1.732$	N.S.
N.C.S.	Factor age :	$F(1,52)=.004$	N.S.
	Factor Pre-Training :	$F(1,52)=.032$	N.S.
	Age x Pre-Training :	$F(1,52)=.006$	N.S.
N.I.S.	Factor age :	$F(1,52)=.482$	N.S.
	Factor Pre-Training :	$F(1,52)=3.127$	N.S.
	Age x Pre-Training :	$F(1,52)=4.046$	$p < .05$
U(S)	Factor age :	$F(1,52)=.64$	N.S.
	Factor Pre-Training :	$F(1,52)=.623$	N.S.
	Age x Pre-Training :	$F(1,52)=1.598$	N.S.
U(C.S.)	Factor age :	$F(1,52)=.007$	N.S.
	Factor Pre-Training :	$F(1,52)=.016$	N.S.
	Age x Pre-Training :	$F(1,52)=.695$	N.S.
U(I.S.)	Factor age :	$F(1,52)=.678$	N.S.
	Factor Pre-Training :	$F(1,52)=4.634$	$p < .04$
	Age x Pre-Training :	$F(1,52)=4.066$	$p < .05$
N.S.D_2	Factor age :	$F(1,52)=.819$	N.S.
	Factor Pre-Training :	$F(1,52)=.066$	N.S.
	Age x Pre-Training :	$F(1,52)=.961$	N.S.
N.S.D_{10}	Factor age :	$F(1,52)=.022$	N.S.
	Factor Pre-Training :	$F(1,52)=.102$	N.S.
	Age x Pre-Training :	$F(1,52)=.193$	N.S.
N.S.C.	Factor age :	$F(1,52)=.503$	N.S.
	Factor Pre-Training :	$F(1,52)=1.737$	N.S.
	Age x Pre-Training :	$F(1,52)=.652$	N.S.

TABLE 2.17 : For each index, ANOVA (age x pre-training) in the fourth session (matrix C).

	14-15y.o. (df=29)	ADULTS (df=20)
%C.S.	t=-.35 N.S.	t=-2.14 *
%D.S.	t=.32 N.S.	t=-1.61 N.S.
N.C.S.	t=-.08 N.S.	t=-.19 N.S.
N.I.S.	t=.10 N.S.	t=2.71 *
U(S)	t=-.19 N.S.	t=1.72 N.S.
U(C.S.)	t=-.41 N.S.	t=.82 N.S.
U(I.S.).	t=.38 N.S.	t=3.11 **
$N.S.D_2$	t=-.40 N.S.	t=1.08 N.S.
$N.S.D_{10}$	t=-.04 N.S.	t=.59 N.S.
N.S.C.	t=-.45 N.S.	t=-1.7 N.S.

<u>TABLE 2.18</u> : For each index, Student T-test (pre-training) in the fourth session (matrix C) for each age-group. (* : p<.05; ** : p<.01).

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	ANOVA (AGE x PRE-TRAINING)		
%C.S.	Factor age :	F(1,52)=.645	N.S.
	Factor Pre-Training :	F(1,52)=.952	N.S.
	Age x Pre-Training :	F(1,52)=.348	N.S.
%D.S.	Factor age :	F(1,52)=1.136	N.S.
	Factor Pre-Training :	F(1,52)=.049	N.S.
	Age x Pre-Training :	F(1,52)=1.303	N.S.
N.C.S.	Factor age :	F(1,52)=.926	N.S.
	Factor Pre-Training :	F(1,52)=.144	N.S.
	Age x Pre-Training :	F(1,52)=4.56	$p < .04$
N.I.S.	Factor age :	F(1,52)=1.009	N.S.
	Factor Pre-Training :	F(1,52)=1.336	N.S.
	Age x Pre-Training :	F(1,52)=.035	N.S.
U(S)	Factor age :	F(1,52)=1.443	N.S.
	Factor Pre-Training :	F(1,52)=.010	N.S.
	Age x Pre-Training :	F(1,52)=2.818	N.S.
U(C.S.)	Factor age :	F(1,52)=1.290	N.S.
	Factor Pre-Training :	F(1,52)=.047	N.S.
	Age x Pre-Training :	F(1,52)=3.011	N.S.
U(I.S.)	Factor age :	F(1,52)=2.062	N.S.
	Factor Pre-Training :	F(1,52)=.489	N.S.
	Age x Pre-Training :	F(1,52)=.388	N.S.
$N.S.D_2$	Factor age :	F(1,52)=1.175	N.S.
	Factor Pre-Training :	F(1,52)=.152	N.S.
	Age x Pre-Training :	F(1,52)=1.436	N.S.
$N.S.D_{10}$	Factor age :	F(1,52)=.487	N.S.
	Factor Pre-Training :	F(1,52)=.030	N.S.
	Age x Pre-Training :	F(1,52)=4.736	$p < .04$
N.S.C.	Factor age :	F(1,52)=4.431	$p < .04$
	Factor Pre-Training :	F(1,52)=.880	N.S.
	Age x Pre-Training :	F(1,52)=.007	N.S.

TABLE 2.19 : For each index, ANOVA (age x pre-training) in the fifth session (matrix N).

		ANOVA (AGE x STUDY)		
		N Global (1st. session)	N (2nd. session)	N (3rd. session)
%C.S.	Factor age :	F(1,169)=.000, NS	F(1,63)=.742, NS	F(1,63)=.179, NS
	Factor Study :	F(1,169)=22.029, p<.000	F(1,63)=.074, NS	F(1,63)=.011, NS
	Age x Study :	F(1,169)=1.890, NS	F(1,63)=.103, NS	F(1,63)=1.140, NS
%D.S.	Factor age :	F(1,169)=.674, NS	F(1,63)=1.479, NS	F(1,63)=2.856, NS
	Factor Study :	F(1,169)=.334, NS	F(1,63)=.355, NS	F(1,63)=.351, NS
	Age x Study :	F(1,169)=.224, NS	F(1,63)=.002, NS	F(1,63)=.180, NS
N.C.S.	Factor age :	F(1,169)=.068, NS	F(1,63)=.439, NS	F(1,63)=1.258, NS
	Factor Study :	F(1,169)=1.322, NS	F(1,63)=.110, NS	F(1,63)=.345, NS
	Age x Study :	F(1,169)=.049, NS	F(1,63)=1.212, NS	F(1,63)=.088, NS
N.I.S.	Factor age :	F(1,169)=.086, NS	F(1,63)=.531, NS	F(1,63)=.103, NS
	Factor Study :	F(1,169)=11.144, p<.001	F(1,63)=.283, NS	F(1,63)=1.583, NS
	Age x Study :	F(1,169)=1.847, NS	F(1,63)=.221, NS	F(1,63)=.617, NS
U(S)	Factor age :	F(1,169)=.449, NS	F(1,63)=1.019, NS	F(1,63)=2.174, NS
	Factor Study :	F(1,169)=.634, NS	F(1,63)=.211, NS	F(1,63)=.694, NS
	Age x Study :	F(1,169)=.037, NS	F(1,63)=.337, NS	F(1,63)=.435, NS
U(C.S.)	Factor age :	F(1,169)=.534, NS	F(1,63)=1.727, NS	F(1,63)=2.850, NS
	Factor Study :	F(1,169)=.493, NS	F(1,63)=.141, NS	F(1,63)=.513, NS
	Age x Study :	F(1,169)=.046, NS	F(1,63)=.479, NS	F(1,63)=.112, NS
U(I.S.)	Factor age :	F(1,169)=.008, NS	F(1,63)=.666, NS	F(1,63)=.006, NS
	Factor Study :	F(1,169)=8.0, p<.005	F(1,63)=.193, NS	F(1,63)=3.334, NS
	Age x Study :	F(1,169)=.878, NS	F(1,63)=.476, NS	F(1,63)=.295, NS
$N.S.D_2$	Factor age :	F(1,169)=2.602, NS	F(1,63)=6.546, p<.02	F(1,63)=4.617, p<.04
	Factor Study :	F(1,169)=2.128, NS	F(1,63)=.357, NS	F(1,63)=.043, NS
	Age x Study :	F(1,169)=.659, NS	F(1,63)=.346, NS	F(1,63)=.068, NS

<u>TABLE 2.20</u> : For each index, ANOVA (age x study) in the first, second and third sessions (NNN).

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	14-15y.o. (df=81)	ADULTS (df=81)
%C.S.	t=4.34 ***	t=2.17 *
%D.S.	t=.11 N.S.	t=.72 N.S.
N.C.S.	t=.98 N.S.	t=.62 N.S.
N.I.S.	t=-3.10 **	t=-1.38 N.S.
U(S)	t=-.72 N.S.	t=-.39 N.S.
U(C.S.)	t=.66 N.S.	t=.31 N.S.
U(I.S.).	t=-2.69 **	t=-1.21 N.S.
$N.S.D_2$	t=1.56 N.S.	t=.39 N.S.

TABLE 2.21 : For each index, Student T-test (study) in N global (first session), for each age-group. (* : p<.05; ** p<.01; *** : p<.001).

	ANOVA (AGE x STUDY)		
%C.S.	Factor age :	F(1,65)=.414	N.S.
	Factor Study :	F(1,65)=6.238	$p < .02$
	Age x Study :	F(1,65)=.425	N.S.
%D.S.	Factor age :	F(1,65)=.098	N.S.
	Factor Study :	F(1,65)=1.037	N.S.
	Age x Study :	F(1,65)=.063	N.S.
N.C.S.	Factor age :	F(1,65)=.004	N.S.
	Factor Study :	F(1,65)=5.418	$p < .03$
	Age x Study :	F(1,65)=.000	N.S.
N.I.S.	Factor age :	F(1,65)=1.060	N.S.
	Factor Study :	F(1,65)=4.940	$p < .03$
	Age x Study :	F(1,65)=.551	N.S.
U(S)	Factor age :	F(1,65)=.117	N.S.
	Factor Study :	F(1,65)=1.582	N.S.
	Age x Study :	F(1,65)=.007	N.S.
U(C.S.)	Factor age :	F(1,65)=.024	N.S.
	Factor Study :	F(1,65)=4.303	$p < .05$
	Age x Study :	F(1,65)=.031	N.S.
U(I.S.)	Factor age :	F(1,65)=.895	N.S.
	Factor Study :	F(1,65)=3.304	N.S.
	Age x Study :	F(1,65)=.002	N.S.
$N.S.D_2$	Factor age :	F(1,65)=.000	N.S.
	Factor Study :	F(1,65)=8.910	$p < .004$
	Age x Study :	F(1,65)=.087	N.S.

TABLE 2.22 : For each index, ANOVA (age x study) in D, in the second session.

	14-15y.o. (df=33)	ADULTS (df=29)
%C.S.	t=1.92 N.S.	t=1.64 N.S.
%D.S.	t=-1.06 N.S.	t=-.44 N.S.
N.C.S.	t=1.95 (*)	t=1.37 N.S.
N.I.S.	t=-1.86 N.S.	t=-1.18 N.S.
U(S)	t=1.11 N.S.	t=.7 N.S.
U(C.S.)	t=1.98 (*)	t=1.07 N.S.
U(I.S.).	t=-1.26 N.S.	t=-1.3 N.S.
$N.S.D_2$	t=2.7 *	t=1.59 N.S.

TABLE 2.23 : For each index, Student T-test (study) in D (second session) for each age-group. ((*) : p=.059; * : p<.05).

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APPENDIX 3

- List of tables

- Tables 3.1 to 3.23

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	N GLOBAL	N	N	N	C
% C S	88 26 (1.26)	89.05 (1.94)	91.40 (2.07)	94.95 (1.68)	92.19 (1.45)
% D S	56.72 (3.58)	55.43 (4.49)	65.20 (5.78)	75.52 (5.69)	52.29 (4.34)
N.C.S.	6.56 (0.53)	6.90 (0.79)	5.25 (0.83)	4.52 (0.80)	10.71 (0.69)
N.I.S.	3.33 (0.28)	2.76 (0.39)	1.95 (0.33)	1.48 (0.43)	3.19 (0.56)
U (S)	2.07 (0.15)	2.13 (0.20)	1.56 (0.23)	1.16 (0.25)	2.56 (0.18)
U (C.S.)	1.59 (0.15)	1.71 (0.19)	1.22 (0.22)	0.96 (0.22)	2.22 (0.19)
U (I.S.)	1.45 (0.12)	1.20 (0.17)	0.60 (0.17)	0.43 (0.18)	1.30 (0.23)
N.S.D2	14.08 (9.87)	15.19 (1.80)	11.90 (2.23)	8.90 (1.82)	19.10 (2.20)
N.S.D10	8.49 (0.76)	9.05 (1.12)	6.95 (1.33)	5.71 (1.15)	13.76 (1.36)
N.S.C.	1.15 (0.50)	1.76 (0.91)	1.15 (0.41)	0.86 (0.30)	26.76 (2.07)

TABLE 3.1 : For each index, mean and standard deviation in N global and in each session of the group NNNC, for the subjects with a school education of technical type (Var 1/T).

	N GLOBAL	N	N	N	C
% C S	93.00 (1.43)	95.20 (0.99)	97.43 (0.85)	97.33 (0.84)	79.33 (4.82)
% D S	72.00 (4.44)	81.33 (3.91)	74 (6.31)	73.87 (7.24)	42.80 (5.46)
N C S	4.80 (0.58)	3.67 (0.56)	3.43 (0.92)	3.47 (0.99)	10.13 (0.58)
N I S	2.27 (0.36)	1.53 (0.26)	0.93 (0.22)	1.00 (0.24)	6.33 (1.20)
U (S)	1.33 (0.19)	0.96 (0.18)	0.97 (0.24)	0.96 (0.28)	3.01 (0.23)
U (C S)	1.02 (0.16)	0.70 (0.15)	0.85 (0.23)	0.83 (0.27)	2.35 (0.16)
U (I S)	0.88 (0.15)	0.53 (0.16)	0.16 (0.11)	0.28 (0.13)	2.00 (0.36)
N S D2	9.87 (1.71)	6.13 (0.98)	6.79 (2.36)	8.80 (3.03)	17.60 (1.51)
N S D10	6.37 (1.00)	4.53 (0.68)	4.36 (1.26)	4.67 (1.57)	12.27 (0.93)
N S C	0.60 (0.26)	0.20 (0.20)	0.57 (0.31)	0.47 (0.32)	21.40 (3.03)

TABLE 3.2 : For each index, mean and standard deviation in N global and in each session of the group NNNC, for the subjects with a school education of non-technical type (Var 1/N-T).

	N	D	D10	C
% C S	87.33 (1.58)	94.44 (1.26)	96.78 (1.02)	97.22 (0.69)
% D S	58.22 (5.84)	21.56 (1.72)	15.11 (0.63)	53.89 (6.17)
N.C.S.	6.17 (0.71)	12.56 (0.82)	15.17 (0.60)	11.67 (0.93)
N.I.S	4.00 (0.34)	2.28 (0.46)	1.39 (0.44)	1.28 (0.27)
U (S)	2.01 (0.22)	3.39 (0.11)	3.73 (0.05)	2.41 (0.26)
U (C.S.)	1.44 (0.23)	3.19 (0.13)	3.62 (0.07)	2.28 (0.26)
U (I.S.)	1.73 (0.16)	0.95 (0.24)	0.51 (0.21)	0.39 (0.16)
N.S.D2	12.78 (2.08)	34.00 (1.60)	40.50 (1.21)	21.94 (2.80)
N.S.D10	7.83 (1.02)	18.72 (1.49)	23.89 (1.16)	15.06 (1.80)
N.S.C.	0.44 (0.15)	3.78 (0.81)	5.78 (0.92)	28.44 (2.82)

TABLE 3.3 : For each index, mean and standard deviation in each session of the group $NDD_{10}C$, for the subjects with a school education of technical type (Var 1/T).

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	N	D	D10	C
% CS	90.80 (2.61)	91.87 (2.32)	95.73 (2.32)	94.53 (3.22)
% DS	62.67 (7.34)	23.33 (2.11)	14.93 (1.23)	51.73 (5.82)
N.C.S.	5.93 (0.95)	12.40 (1.08)	16.07 (0.93)	11.60 (0.87)
N.I.S.	3.00 (0.62)	2.60 (0.51)	1.40 (0.48)	1.67 (0.69)
U (S)	1.70 (0.31)	3.33 (0.13)	3.82 (0.07)	2.51 (0.23)
U (C.S.)	1.33 (0.27)	3.06 (0.17)	3.68 (0.14)	2.31 (0.23)
U (I.S.)	1.23 (0.24)	1.09 (0.24)	0.44 (0.21)	0.58 (0.26)
N.S.D2	13.60 (3.02)	35.33 (2.02)	43.07 (1.88)	22.53 (2.85)
N.S.D10	8.20 (1.78)	18.33 (1.75)	28.13 (2.04)	14.80 (1.53)
N.S.C	1.00 (0.46)	3.00 (0.70)	5.93 (0.76)	26.33 (3.07)

TABLE 3.4 : For each index, mean and standard deviation in each session of the group $NDD_{10}C$, for the subjects with a school education of non-technical type. (Var 1/N-T).

	N GLOBAL	N	N	N	C
% C S	89.14 (2.01)	90.40 (3.47)	93.00 (3.49)	94.80 (2.70)	87.40 (5.47)
% D S	61.24 (5.60)	64.00 (7.65)	67.00 (8.77)	66.00 (9.35)	52.60 (6.23)
N.C.S.	6.29 (0.83)	6.50 (1.32)	4.70 (1.28)	5.20 (1.44)	10.30 (0.97)
N.I.S	3.10 (0.41)	2.40 (0.69)	1.50 (0.52)	1.20 (0.51)	4.20 (1.19)
U (S)	1.90 (0.24)	1.83 (0.36)	1.39 (0.35)	1.42 (0.39)	2.59 (0.28)
U (C.S.)	1.46 (0.23)	1.46 (0.33)	1.13 (0.33)	1.24 (0.35)	2.14 (0.22)
U (I.S.)	1.31 (0.18)	0.91 (0.27)	0.34 (0.23)	0.40 (0.23)	1.61 (0.35)
N.S.D2	13.52 (2.22)	13.60 (2.90)	10.60 (3.53)	10.90 (3.03)	17.20 (1.91)
N.S.D10	8.52 (1.26)	8.70 (1.81)	6.20 (2.12)	6.60 (1.94)	12.30 (1.23)
N.S.C.	1.05 (0.37)	0.90 (0.43)	1.10 (0.57)	1.00 (0.52)	26.90 (3.37)

TABLE 3.5 : For each index, mean and standard deviation in N global and in each session of the group NNNC, for the subjects with a lower level of school education (Var 2/L).

	N GLOBAL	N	N	N	C
% C S	91.40 (1.60)	92.31 (1.84)	93.00 (2.43)	95.08 (1.96)	88.46 (3.24)
% D S	69.50 (4.86)	70.31 (5.87)	72.33 (7.19)	78.77 (7.66)	53.69 (4.24)
N C S	4.90 (0.60)	4.46 (0.74)	3.83 (0.78)	3.62 (0.81)	9.77 (0.54)
N I S	2.60 (0.41)	2.15 (0.37)	1.42 (0.42)	1.62 (0.58)	4.23 (1.03)
U (S)	1.52 (0.22)	1.43 (0.26)	1.14 (0.26)	0.99 (0.32)	2.55 (0.20)
U (C S)	1.13 (0.19)	1.09 (0.23)	0.87 (0.23)	0.77 (0.29)	2.08 (0.15)
U (I S.)	1.04 (0.20)	0.86 (0.21)	0.41 (0.20)	0.46 (0.23)	1.46 (0.38)
N S D2	11.10 (1.96)	10.38 (2.27)	7.50 (1.84)	8.08 (2.90)	15.92 (1.42)
N S D10	6.45 (1.05)	5.92 (1.26)	4.92 (0.97)	5.00 (1.55)	11.85 (0.89)
N S C	0.30 (0.21)	0.31 (0.31)	0.58 (0.29)	0.62 (0.37)	27.15 (2.08)

TABLE 3.6 : For each index, mean and standard deviation in N global and in each session of the group NNNC, for the subjects with a medium level of school education (Var 2/M).

	N GLOBAL	N	N	N	C
% C S	90.43 (1.55)	91.85 (1.76)	95.50 (0.99)	97.69 (0.67)	84.77 (4.22)
% D S	60.57 (4.73)	63.85 (6.48)	66.83 (7.09)	77.69 (6.46)	39.69 (6.76)
N.C.S	6.07 (0.65)	5.92 (0.99)	5.00 (1.26)	3.69 (1.07)	11.31 (0.90)
N I S	2.89 (0.38)	2.23 (0.41)	1.67 (0.28)	1.00 (0.28)	5.00 (1.19)
U (S)	1.80 (0.20)	1.70 (0.28)	1.43 (0.31)	0.90 (0.26)	3.08 (0.27)
U (C S)	1.40 (0.18)	1.36 (0.25)	1.22 (0.30)	0.78 (0.25)	2.56 (0.27)
U (I S)	1.23 (0.16)	0.99 (0.22)	0.49 (0.19)	0.24 (0.16)	1.70 (0.35)
N S D2	12.11 (1.62)	10.77 (2.04)	11.42 (3.33)	8.08 (2.68)	22.00 (3.23)
N S D10	7.64 (0.94)	7.23 (1.17)	6.58 (1.90)	4.54 (1.47)	15.08 (2.03)
N S C.	1.25 (0.68)	2.08 (1.44)	1.08 (0.56)	0.54 (0.31)	20.08 (3.46)

TABLE 3.7 : For each index, mean and standard deviation in N global and in each session of the group NNNC, for the subjects with a upper level of school education (Var 2/U).

	N	D	D10	C
% CS	88.00 (2.29)	94.55 (1.66)	98.00 (0.89)	97.45 (0.47)
% DS	58.73 (8.39)	22.00 (2.63)	14.73 (0.91)	49.09 (6.48)
NCS	6.09 (1.08)	12.82 (1.16)	15.73 (0.70)	12.36 (0.79)
NIS	3.73 (0.41)	2.18 (0.55)	1.00 (0.45)	1.27 (0.24)
U (S)	1.96 (0.33)	3.37 (0.17)	3.75 (0.06)	2.62 (0.23)
U (CS)	1.45 (0.34)	3.18 (0.19)	3.67 (0.09)	2.50 (0.24)
U (IS)	1.68 (0.17)	0.98 (0.29)	0.30 (0.22)	0.32 (0.17)
NSD2	13.45 (3.45)	33.64 (2.22)	41.55 (1.45)	24.27 (2.82)
NSD10	8.36 (1.83)	18.91 (2.31)	24.64 (1.51)	16.00 (1.66)
NSC	1.18 (0.62)	2.73 (0.63)	5.73 (1.00)	26.45 (2.94)

TABLE 3.8 : For each index, mean and standard deviation in each session of the group $NDD_{10}C$, for the subjects with a lower level of school education (Var 2/L).

	N	D	D10	C
% C S	89.71 (3.13)	93.71 (1.77)	96.00 (1.95)	97.14 (0.74)
% D S	68.00 (9.21)	22.86 (2.34)	14.86 (0.86)	37.71 (9.90)
N.C.S.	5.71 (1.02)	12.43 (1.04)	15.57 (1.09)	13.71 (1.48)
N.I.S.	3.43 (0.92)	2.57 (0.69)	1.71 (0.81)	1.43 (0.37)
U (S)	1.69 (0.41)	3.37 (0.12)	3.78 (0.06)	3.04 (0.40)
U (C.S.)	1.22 (0.34)	3.14 (0.14)	3.64 (0.11)	2.93 (0.40)
U (I.S.)	1.38 (0.40)	1.15 (0.35)	0.57 (0.39)	0.51 (0.25)
N.S.D2	12.43 (3.90)	35.14 (2.61)	42.29 (2.01)	30.57 (5.09)
N.S.D10	7.43 (1.94)	18.57 (1.94)	25.86 (1.97)	19.29 (3.14)
N.S.C.	0.29 (0.18)	4.43 (1.73)	5.86 (1.44)	21.14 (4.49)

TABLE 3.9 : For each index, mean and standard deviation in each session of the group $NDD_{10}C$, for the subjects with a medium level of school education (Var 2/M).

	N	D	D10	C
% CS	89.20 (2.48)	92.13 (2.39)	95.20 (2.36)	94.40 (3.28)
% DS	57.73 (6.93)	22.40 (2.04)	15.33 (1.23)	62.80 (5.70)
NCS	6.20 (0.90)	12.27 (1.10)	15.47 (0.96)	10.13 (0.96)
NIS	3.47 (0.58)	2.53 (0.55)	1.53 (0.52)	1.60 (0.73)
U (S)	1.88 (0.28)	3.35 (0.12)	3.78 (0.08)	2.07 (0.26)
U (CS)	1.43 (0.26)	3.08 (0.18)	3.63 (0.15)	1.85 (0.23)
U (IS)	1.43 (0.23)	0.97 (0.27)	0.57 (0.23)	0.57 (0.28)
NSD2	13.27 (2.48)	35.07 (1.96)	41.47 (2.00)	16.80 (2.36)
NSD10	8.00 (1.47)	18.27 (1.66)	26.67 (2.17)	12.13 (1.55)
NSC	0.53 (0.17)	3.47 (0.78)	5.93 (0.93)	31.20 (3.20)

TABLE 3.10 : For each index, mean and standard deviation in each session of the group $NDD_{10}C$, for the subjects with a upper level of school education (Var 2/U).

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	F	N GLOBAL		N		N		N		C	
% C S	1	6.31	p= .01	5.86	p= .02	5.35	p= .02	1.18	NS	8.73	p= .006
	2	0.44	NS	0.19	NS	0.43	NS	0.74	NS	0.28	NS
	3	2.38	NS	0.62	NS	1.25	NS	0.17	NS	2.12	NS
% D S	1	7.36	p= .008	15.48	p= .0005	0.98	NS	0.03	NS	1.86	NS
	2	0.99	NS	0.45	NS	0.18	NS	0.78	NS	1.81	NS
	3	1.08	NS	0.00	NS	1.20	NS	1.87	NS	0.00	NS
N.C.S.	1	4.87	p= .03	8.93	p= .005	1.96	NS	0.69	NS	0.36	NS
	2	1.07	NS	1.28	NS	0.31	NS	0.61	NS	0.97	NS
	3	0.47	NS	0.00	NS	0.64	NS	1.24	NS	0.53	NS
N.I.S.	1	5.8	p= .01	5.36	p= .02	5.04	p= .03	0.70	NS	7.08	p= .01
	2	0.38	NS	0.07	NS	0.11	NS	0.45	NS	0.21	NS
	3	1.88	NS	0.67	NS	0.51	NS	0.26	NS	2.60	NS
U (S)	1	9.87	p= .002	15.83	p= .0004	2.72	NS	0.29	NS	2.29	NS
	2	0.83	NS	0.64	NS	0.27	NS	0.69	NS	1.46	NS
	3	1.02	NS	0.00	NS	0.78	NS	1.35	NS	0.38	NS
U (CS)	1	6.49	p= .01	13.73	p= .0009	1.23	NS	0.15	NS	0.24	NS
	2	0.75	NS	0.70	NS	0.40	NS	0.79	NS	1.42	NS
	3	0.72	NS	0.00	NS	0.72	NS	1.68	NS	0.23	NS
U (IS)	1	8.51	p= .004	7.03	p= .01	3.28	NS	0.38	NS	3.15	NS
	2	0.61	NS	0.10	NS	0.13	NS	0.33	NS	0.13	NS
	3	1.18	NS	0.47	NS	0.13	NS	0.18	NS	2.52	NS
N.S.D2	1	3.78	p= .05	14.29	p= .0007	2.28	NS	0.00	NS	0.27	NS
	2	0.38	NS	0.67	NS	0.54	NS	0.30	NS	1.81	NS
	3	1.26	NS	0.00	NS	0.89	NS	2.01	NS	0.54	NS
N.S.D10	1	2.92	NS	9.17	p= .005	1.71	NS	0.29	NS	0.69	NS
	2	0.85	NS	1.12	NS	0.28	NS	0.38	NS	1.36	NS
	3	0.61	NS	0.00	NS	0.69	NS	0.98	NS	0.45	NS
N.S.C.	1	0.83	NS	1.97	NS	1.06	NS	0.72	NS	2.27	NS
	2	0.88	NS	0.97	NS	0.39	NS	0.36	NS	1.82	NS
	3	1.60	NS	0.50	NS	1.00	NS	0.80	NS	0.00	NS

TABLE 3.11 : For each index, ANOVA (type x level) in N global and in each session, of the group NNNC.
1 = factor type, in N global : $F(1,68)$; in NNNC : $F(1,35)$
2 = factor level, in N global : $F(2,68)$; in NNNC : $F(2,35)$
3 = factor type x level, in N global : $F(2,68)$; in NNNC : $F(2,35)$

	F	N		D		D10		C	
% C S	1	1.34	NS	0.94	NS	0.17	NS	0.70	NS
	2	0.10	NS	0.34	NS	0.49	NS	0.42	NS
	3	1.28	NS	0.17	NS	0.13	NS	0.00	NS
% D S	1	0.22	NS	0.41	NS	0.02	NS	0.07	NS
	2	0.36	NS	0.02	NS	0.08	NS	3.19	p= .05
	3	0.80	NS	0.95	NS	0.25	NS	1.74	NS
N.C.S.	1	0.04	NS	0.01	NS	0.62	NS	0.00	NS
	2	0.05	NS	0.06	NS	0.02	NS	2.75	NS
	3	0.70	NS	0.65	NS	0.19	NS	0.43	NS
N.I.S.	1	2.09	NS	0.2	NS	0.00	NS	0.27	NS
	2	0.07	NS	0.11	NS	0.35	NS	0.08	NS
	3	1.25	NS	0.00	NS	0.20	NS	0.00	NS
U (S)	1	0.62	NS	0.11	NS	1.12	NS	0.09	NS
	2	0.14	NS	0.01	NS	0.07	NS	2.74	NS
	3	0.90	NS	0.00	NS	0.07	NS	1.08	NS
U (C S)	1	0.019	NS	0.32	NS	0.15	NS	0.00	NS
	2	0.13	NS	0.08	NS	0.03	NS	3.73	p= .03
	3	0.16	NS	0.00	NS	0.16	NS	1.2	NS
U (I S)	1	3.23	NS	0.15	NS	0.05	NS	0.36	NS
	2	0.41	NS	0.08	NS	0.34	NS	0.26	NS
	3	0.75	NS	0.10	NS	0.55	NS	0.23	NS
N.S.D2	1	0.05	NS	0.28	NS	1.24	NS	0.03	NS
	2	0.02	NS	0.15	NS	0.04	NS	4.86	p= .01
	3	1.41	NS	1.92	NS	0.2	NS	2.09	NS
N.S.D10	1	0.03	NS	0.03	NS	3.16	p= 0.08	0.01	NS
	2	0.06	NS	0.03	NS	0.28	NS	3.05	NS
	3	1.18	NS	0.11	NS	0.00	NS	0.69	NS
N.S.C	1	2.32	NS	0.49	NS	0.02	NS	0.27	NS
	2	1.91	NS	0.61	NS	0.01	NS	1.87	NS
	3	7.72	p= .002	0.95	NS	1.0	NS	1.10	NS

TABLE 3.12 : For each index, ANOVA (type x level) in each session of the group $NDD_{10}C$.

1 = factor type : $F(1,32)$
2 = factor level : $F(2,32)$
3 = factor type x level : $F(2,32)$

	N GLOBAL	N	N	N	C
% C S	t = -2.48 *	t = -2.51 *	t = -2.33 *	t = -1.12 NS	t = 2.92 **
% D S	t = -2.71 **	t = -4.14 ***	t = -1.01 NS	t = 0.18 NS	t = 1.37 NS
N C S	t = 2.22 *	t = 3.08 **	t = 1.45 NS	t = 0.83 NS	t = 0.61 NS
N I S	t = 2.40 *	t = 2.41 *	t = 2.35 *	t = 0.87 NS	t = -2.60 *
U (S)	t = 3.15 **	t = 4.17 ***	t = 1.70 NS	t = 0.54 NS	t = -1.52 NS
U (CS)	t = 2.57 **	t = 3.89 ***	t = 1.14 NS	t = 0.39 NS	t = -0.49 NS
U (I S)	t = 2.93 **	t = 2.77 **	t = 1.91 NS	t = 0.65 NS	t = -1.74 NS
N S D2	t = 1.95 *	t = 3.95 ***	t = 1.54 NS	t = 0.03 NS	t = 0.51 NS
N S D10	t = 1.72 NS	t = 3.12 **	t = 1.35 NS	t = 0.55 NS	t = 0.83 NS
N S C	t = 0.90 NS	t = 1.43 NS	t = 1.05 NS	t = 0.86 NS	t = 1.51 NS

TABLE 3.13 : Student T-test (type of school education) in N global and in each session of the group NNNC (* : p<.05; ** : p<.01; *** : p<.001; NS : no significant).

	N	D	D10	C
% C S	t = -1.18 NS	t = 1.02 NS	t = 0.43 NS	t = 0.89 NS
% D S	t = -0.48 NS	t = -0.66 NS	t = 0.13 NS	t = 0.25 NS
N.C.S.	t = 0.20 NS	t = 0.12 NS	t = -0.84 NS	t = 0.05 NS
N.I.S.	t = 1.48 NS	t = -0.47 NS	t = -0.01 NS	t = -0.56 NS
U (S)	t = 0.81 NS	t = 0.35 NS	t = -1.13 NS	t = -0.29 NS
U (C.S.)	t = 0.31 NS	t = 0.60 NS	t = -0.41 NS	t = -0.06 NS
U (I.S.)	t = 1.85 NS	t = -0.41 NS	t = 0.23 NS	t = -0.63 NS
N.S.D2	t = -0.23 NS	t = -0.52 NS	t = -1.18 NS	t = -0.15 NS
N.S.D10	t = -0.19 NS	t = 0.17 NS	t = -1.88 NS	t = 0.11 NS
N.S.C.	t = -1.25 NS	t = 0.71 NS	t = -0.13 NS	t = 0.51 NS

TABLE 3.14 : Student T-test (type of school education) in each session of the group $NDD_{10}C$.

	ANOVA (GROUP X TYPE)		
% CS	FACTOR GROUP	F (1, 68) = 2.05	NS
	FACTOR TYPE	F (1, 68) = 6.23	**
	GROUP X TYPE	F (1, 68) = 0.78	NS
% DS	FACTOR GROUP	F (1, 68) = 1.20	NS
	FACTOR TYPE	F (1, 68) = 7.70	**
	GROUP X TYPE	F (1, 68) = 4.03	*
N.C.S.	FACTOR GROUP	F (1, 68) = 0.42	NS
	FACTOR TYPE	F (1, 68) = 5.10	*
	GROUP X TYPE	F (1, 68) = 3.81	*
N.I.S.	FACTOR GROUP	F (1, 68) = 9.70	**
	FACTOR TYPE	F (1, 68) = 6.48	**
	GROUP X TYPE	F (1, 68) = 0.70	NS
U (S)	FACTOR GROUP	F (1, 68) = 0.99	NS
	FACTOR TYPE	F (1, 68) = 10.32	**
	GROUP X TYPE	F (1, 68) = 3.79	*
U (C.S.)	FACTOR GROUP	F (1, 68) = 0.24	NS
	FACTOR TYPE	F (1, 68) = 6.84	**
	GROUP X TYPE	F (1, 68) = 4.35	*
U (I.S.)	FACTOR GROUP	F (1, 68) = 10.25	**
	FACTOR TYPE	F (1, 68) = 9.75	**
	GROUP X TYPE	F (1, 68) = 0.99	NS
N.S.D2	FACTOR GROUP	F (1, 68) = 0.70	NS
	FACTOR TYPE	F (1, 68) = 4.07	*
	GROUP X TYPE	F (1, 68) = 5.72	*
N.S.D10	FACTOR GROUP	F (1, 68) = 0.48	NS
	FACTOR TYPE	F (1, 68) = 3.09	NS
	GROUP X TYPE	F (1, 68) = 4.18	*
N.S.D	FACTOR GROUP	F (1, 68) = 0.47	NS
	FACTOR TYPE	F (1, 68) = 0.83	NS
	GROUP X TYPE	F (1, 68) = 2.98	NS

TABLE 3.15 : For each index, ANOVA (group x type) in the first session (matrix N).

	N - N (df = 67,0)	N - D (df = 65,0)	C - C (df = 67,0)
% C S	t = - 1.38 NS	t = - 0.33 NS	t = 3.18 **
% D S	t = - 1.02 NS	t = - 10.22 ***	t = 0.84 NS
N.C.S	t = 0.62 NS	t = 8.82 ***	t = 1.50 NS
N.I.S	t = 3.00 **	t = 2.22 *	t = - 4.07 ***
U (S)	t = 0.91 NS	t = 10.58 ***	t = - 1.30 NS
U (C.S)	t = 0.45 NS	t = 10.57 ***	t = 0.12 NS
U (I.S)	t = 3.01 **	t = 2.94 **	t = - 4.35 ***
N.S.D2	t = 0.79 NS	t = 11.84 ***	t = 1.56 NS
N.S.D10	t = 0.67 NS	t = 8.63 ***	t = 1.23
N.S.C	t = - 0.68 NS	t = 4.18 ***	t = 1.09 NS

TABLE 3.16 : For each index, Student T-test in the first, the second and the fourth sessions, for the global population.
(* : p<.05; ** : p<.01; *** : p<.001; NS : no significant).

	ANOVA (MATRIX X TYPE)		
% C S	FACTOR MATRIX	F (1, 68) = 0.12	N S
	FACTOR TYPE	F (1, 68) = 0.90	N S
	MATRIX X TYPE	F (1, 68) = 5.71	*
% D S	FACTOR MATRIX	F (1, 68) = 104.4	***
	FACTOR TYPE	F (1, 68) = 0.51	N S
	MATRIX X TYPE	F (1, 68) = 1.41	N S
N.C.S.	FACTOR MATRIX	F (1, 68) = 77.74	***
	FACTOR TYPE	F (1, 68) = 0.48	N S
	MATRIX X TYPE	F (1, 68) = 1.51	N S
N I S	FACTOR MATRIX	F (1, 68) = 5.06	*
	FACTOR TYPE	F (1, 68) = 0.60	N S
	MATRIX X TYPE	F (1, 68) = 2.96	N S
U (S)	FACTOR MATRIX	F (1, 68) = 116.55	***
	FACTOR TYPE	F (1, 68) = 1.48	N S
	MATRIX X TYPE	F (1, 68) = 3.24	N S
U (C S)	FACTOR MATRIX	F (1, 68) = 111.84	***
	FACTOR TYPE	F (1, 68) = 0.68	N S
	MATRIX X TYPE	F (1, 68) = 1.37	N S
U (I S)	FACTOR MATRIX	F (1, 68) = 8.72	**
	FACTOR TYPE	F (1, 68) = 0.36	N S
	MATRIX X TYPE	F (1, 68) = 2.18	N S
N.S.D2	FACTOR MATRIX	F (1, 68) = 142.64	***
	MATRIX X TYPE	F (1, 68) = 0.15	N S
	MATRIX X TYPE	F (1, 68) = 3.03	N S
N.S.D10	FACTOR MATRIX	F (1, 68) = 73.90	***
	FACTOR TYPE	F (1, 68) = 0.40	N S
	MATRIX X TYPE	F (1, 68) = 1.16	N S
N S D	FACTOR MATRIX	F (1, 68) = 17.29	**
	FACTOR TYPE	F (1, 68) = 0.87	N S
	MATRIX X TYPE	F (1, 68) = 0.40	N S

<u>TABLE 3.17</u> : For each index, ANOVA (Matrix x Type) in the second session (N and D, after N).

	T (df = 36)	N - T (df = 27)
% C.S	t = - 1.25 NS	t = 2.24 *
% D.S	t = 7.23 ***	t = 7.61 ***
N.C.S	t = - 6.23 ***	t = - 6.29 ***
N.I.S	t = - 0.59 NS	t = - 3.03 **
U (S)	t = - 7.22 ***	t = - 8.55 ***
U (C.S)	t = - 7.62 ***	t = - 7.71 ***
U (I.S)	t = - 1.20 NS	t = - 3.56 **
N.S.D2	t = - 7.87 ***	t = - 9.23 ***
N.S.D10	t = - 5.91 ***	t = - 6.38 ***
N.C.S.	t = - 2.88 **	t = - 3.18 **

TABLE 3.18 : For each index, Student T-test (Matrix) in the second session, for each type of school education. (* : p<.05; ** : p<.01; *** : p<.001; NS : no significant).

	ANOVA (PRE - TRAINING X TYPE)		
% C S	FACTOR PRE-TRAINING	F (1, 68) = 11.64	**
	FACTOR TYPE	F (1, 68) = 7.84	**
	PRE-TRAINING X TYPE	F (1, 68) = 4.27	*
% D S	FACTOR PRE-TRAINING	F (1, 68) = 0.71	N S
	FACTOR TYPE	F (1, 68) = 1.11	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.52	N S
N C.S.	FACTOR PRE-TRAINING	F (1, 68) = 2.19	N S
	FACTOR TYPE	F (1, 68) = 0.13	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.15	N S
N I S	FACTOR PRE-TRAINING	F (1, 68) = 18.62	***
	FACTOR TYPE	F (1, 68) = 5.66	*
	PRE-TRAINING X TYPE	F (1, 68) = 4.56	*
U (S)	FACTOR PRE-TRAINING	F (1, 68) = 1.69	N S
	FACTOR TYPE	F (1, 68) = 1.38	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.69	N S
U (C S)	FACTOR PRE-TRAINING	F (1, 68) = 0.01	N S
	FACTOR TYPE	F (1, 68) = 0.19	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.06	N S
U (I S)	FACTOR PRE-TRAINING	F (1, 68) = 19.545	***
	FACTOR TYPE	F (1, 68) = 2.63	N S
	PRE-TRAINING X TYPE	F (1, 68) = 1.63	N S
N S D2	FACTOR PRE-TRAINING	F (1, 68) = 2.36	N S
	FACTOR TYPE	F (1, 68) = 0.02	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.205	N S
N S D10	FACTOR PRE-TRAINING	F (1, 68) = 1.49	N S
	FACTOR TYPE	F (1, 68) = 0.31	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.23	N S
N S D	FACTOR PRE-TRAINING	F (1, 68) = 1.205	N S
	FACTOR TYPE	F (1, 68) = 1.83	N S
	PRE-TRAINING X TYPE	F (1, 68) = 0.47	N S

<u>TABLE 3.19</u> : For each index, ANOVA (pre-training x type) in the fourth session (matrix C).

	T (df = 36)	N - T (df = 27)
% C.S	t = - 2.85 **	t = - 2.39 *
% D.S	t = - 0.23 NS	t = - 0.84 NS
N.C.S	t = - 0.74 NS	t = - 1.40 NS
N.I.S	t = 2.80 **	t = 3.09 **
U (S)	t = 0.47 NS	t = 1.27 NS
U (C.S)	t = - 0.15 NS	t = - 0.06 NS
U (I.S)	t = 2.93 **	t = 2.99 **
N.S.D2	t = - 0.70 NS	t = - 1.72 NS
N.S.D10	t = - 0.50 NS	t = - 1.47 NS
N.C.S.	t = - 0.49 NS	t = - 0.88 NS

TABLE 3.20 : For each index, Student T-test (Matrix) in the fourth session, for each type of school education. (* : p<.05; ** : p<.01; NS : no significant).

N global

	A	E
% CS	91,20	89,47
% DS	66,40	60,95
NCS	5,43	6,11
NIS	2,90	2,95
U (S)	1,63	1,85
U (CS)	1,23	1,42
U (IS)	1,21	1,20
NSD2	12,30	12,18
NSD10	7,17	7,89
NCS	1,07	0,71

Tab. 3.21.

For each index, means according to the subjects' cognitive style, in N global. In N global, 30 Assimilators (A) and 38 Explorers (E).

	N		N		C	
	A	E	A	E	A	E
% CS	94,13	93,67	95,76	96,11	84,5	90,44
% DS	71,5	66,44	81,41	68,95	46,63	51,44
NCS	3,94	5,00	3,00	5,05	10,44	10,56
NIS	1,25	1,78	1,00	1,53	5,19	3,56
U(S)	1,13	1,48	0,78	1,35	2,84	2,61
U(CS)	0,89	1,23	0,59	1,18	2,29	2,23
U(IS)	0,26	0,55	0,21	0,5	1,76	1,32
NSD2	9	10,5	5,82	11,58	17,5	19,22
NSD10	5,06	6,61	3,82	6	13,06	13,22
NCS	0,50	1,28	0,18	1,16	23,5	26,28

Tab. 3.22.

For each index, means according to the subjects' cognitive style, in the sessions 2, 3 and 4 of the experimental group NNNC (16A and 18E).

	D		D10		C	
	A	E	A	E	A	E
% CS	95,38	91,79	98,46	94,84	97,37	94,95
% DS	21,85	23,05	14,15	15,79	55,08	53,16
NCS	13,38	11,79	16,38	15,05	11,92	11,47
NIS	2,00	2,68	0,69	1,84	1,15	1,68
U(S)	3,41	3,32	3,81	3,74	2,44	2,44
U(CS)	3,25	3,03	3,76	3,56	2,32	2,24
U(IS)	0,81	1,12	0,08	0,73	0,38	0,57
NSD2	34,85	34,42	43,54	40,47	21,46	21,84
NSD10	19,31	17,89	26,54	25,21	5,38	14,63
NCS	3,54	3,42	5,62	5,79	28,46	27,21

Tab. 3.23.

For each index, means according to the subjects' cognitive style, in the sessions 2, 3 and 4 of the experimental group NDD10C (14A and 20E).

AD

BEHAVIORAL VARIABILITY, LEARNING PROCESSES AND CREATIVITY

Final Technical Report

Volume B :
Appendix 4

by

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December, 1988

United States Army

EUROPEAN RESEARCH OFFICE OF THE U.S. ARMY

London England

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Marc N. Richelle

APPENDIX 4

Papers related to the study of variability published, submitted or presented at conferences during the period covered by this project.

In addition to the papers reproduced here, other related papers are :

- Variation and Selection : The Evolutionary Analogy in Skinner's Theory, by M. Richelle. In S. Modgil & C. Modgil (Eds) B.F. Skinner, Consensus and Controversy. Philadelphia, The Falmer Press, Taylor and Francis Inc, 1987, 127-137

- Le développement de la variabilité comportementale chez l'humain, by B. Boulanger. Doctoral thesis to be submitted to University of Liège, 1989

Moreover, presentations of parts of the material reported have been made at various Scientific Meetings :

- How to train pigeons to vary their sequences ?, by B. Boulanger. Poster presented at the Annual Meeting of the Belgian Society of Psychology. Bruxelles, Belgium, May, 1986

- Conditioning variability in humans : a developmental approach, by B. Boulanger. Paper presented at the Second European Meeting of the Experimental Analysis of Behavior, Liège, Belgium, July 1988

- Symposium on Behavioral Variability in Learning and Cognitive processes. Organized by M. Richelle as an invited symposium at the Sidney International Congress of Psychology. August 26 - September 3, 1988. With participation as invited speakers of J. Delius, Konstanz (F.R.G.), J.E.R. Staddon (Duke University, U.S.), P. Bovet (CNRS Laboratory, Marseille), G. Lautrey (Université René Descartes, Paris).
  M. Richelle's introductory paper "Looking at Variability in its own right", was a shortened version of chapter 2.1.

- M. Richelle, Main investigator, has been invited to lecture on Behavioral Variability in various places during the period covered by the contract. These include the Hungarian Academy of Sciences in Budapest, the University of Neuchatel in Switzerland, the University of Lisboa in Portugal and the University of Lille in France.

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CAN WE TEACH SCIENTIFIC CREATIVITY ?
An experimental psychologist's point of view.

This is a revised version of a paper delivered at the the symposium Science, Creativity and Education. Firenze, December 1986.

Theoretical and experimental work presented in this paper has been made possible thanks to grants from the Belgian Fonds National de la Recherche Scientifique and the U.S. Army European Research Office (Basic Research in Behavioral and Social Sciences).

Overt concern for creativity in education and in psychology is rather recent; it goes back, roughly, to the fifties. If asked for an explanation, most people, especially in educational circles, would probably declare that members of the teaching community, had, by that time, developed new insights as to the role of schools, and that the old view of teachers as transmitting knowledge had given place to a new look, emphasizing the fostering of creative minds. A closer look at history, recent as it is, suggests a less idealistic account (Richelle and Botson, 1974). Psychologists and specialists of education became much concerned with creativity in the United States of America in a peculiar period : competition between the two superpowers was exacerbated by the cold war, and the progresses of Soviet technology threw doubt on the efficiency of the American educational system, especially in science teaching. People started talking a lot about creativity, because it had become scarce, just as they start talking about money or oil when there is a shortage of these items. This is, admittedly, not the single cause of the awareness for and of the subsequent interest in the problem of creativity. Specialists in education and in psychology are certainly to be credited for their penetrating new approaches to a hitherto neglected domain. There is no question about that. However, creative activities have been with us for thousands of years, with no need for any deliberate steps towards inducing them.

These preliminary remarks are intended to remind us of an essential, though, at first sight, trivial point. Whatever we might have to say or to know about the nature of creativity or about its psychological conditions, in terms of intelligence, underlying cognitive mechanisms, personality, learning and so on, socio-cultural factors are undoubtedly crucial in generating creative activities in humans. This should be kept in mind by all those who attempt to improve school curricula, teaching procedures, assessment methods for detecting or producing talents or geniuses. Their task might be futile if not backed by a sociocultural context. Cultural history as well as comparative sociology are, in that respect, essential sources of information, that should not be left aside by any person concerned. This is to say that the problem of creativity, and more specifically of scientific creativity, cannot be approached from one single point of view, but is typically an object for pluridisciplinary approach. This precaution was necessary in order to avoid misunderstandings about the ideas developed below, and to frame them correctly in a wider perspective.

The question " Can we teach scientific creativity ? " might sound strange, for different reasons, to different audiences. To science teachers, traditionnally required to teach science, it will evoke an unusual assignment, far beyond their recognized competence and far beyond the competence of their students, and, anyhow, impossible to fulfill with the ordinary facilities at hand. To productive scientists, who probably do not remember having been taught that subject matter, it will induce a reply like : "Do good research and ,eventually, something new will come out of it". In some psychologists and people in education sharing a view that is still prevalent in many circles, it will provoke the objection : creativity is not the kind of thing you can teach because people are born with (or without) it. Common sense might simply point to our ignorance of the nature of creativity, and consequently to the obvious difficulty in teaching something you don't know anything about.

An efficient though crude solution to the problem might be to go on doing what has been done in the past, that is transmitting scientific know-how somewhat after the tradition of craftmanship. As it seems this way is no longer fully satisfactory. Creative productions in science do not match the expectancies or are not commensurate to the

economic and intellectual investment in science education. But what else can be done is not clear.

Psychologists have not been of great help, and, worse than that, some of them have contributed to mislead teachers by statements that, to say the least, are not based on objective observations. As pointed out above, the question of teaching scientific (or other) creativity has no object at all for those who think of creativity as an inborn capacity that demands only to flourish with as little constraint as possible. This view is far from being typical of anti school and similar movements. It has been shared and advocated in the 1970s by influential decision makers in scientific and technological education. One of them used the unequivocal formula : "You cannot teach creativity, all you can do is liberate it " (Schwartz, L., 1973).

Supposing you praise creativity above anything else, say information or know-how, you might logically suggest, following that sort of statement, that we should give up teaching. Nobody has really taken that risk, especially as far as science teaching is concerned, but that view has probably generated among teachers the uncomfortable feeling that their teaching might have an adverse effect on an ability that is supposed to need only to be freed from (undefined) constraints rather than to be fed by systematic instruction. Teachers were left with no guidelines for action and were diverted from looking for inspiration in fields of psychology relevant to education, in which the vague notion of creativity has little place. Psychology of learning has been especially in disrepute because learning processes have been much identified with the passive shaping in an organism of rigid, stereotyped, fully predictable responses - all the opposite of creativity. More about that below.

If we want to progress in our understanding of scientific creativity and altogether in improving scientific education, we must first get rid of such oversimplifications and bring back our problem in a theoretical and methodological framework that will allow empirical enquiry.

As a first step, it seems advisable to replace the word creativity by creative behaviors. While we might never reach a consensus on what creativity is, we can agree on the critical dimensions of certain behaviors, or of their outcomes, that we call creative. In the field of science, we might like to use the number of Nobel Prizes per million of citizens, or the percentage of elementary school pupils eventually earning their Ph.D., or the number of technological inventions registered per year, and so on.

We shall not, for example, give the label creative to a behavior that is not, in some way novel. Novelty needs of course to be qualified by reference to some set of previously produced behaviors. All behaviors that appear for the first time in the course of individual developement are, in some sense, novel by reference to what the child had done until then. But this is obviously not what we have in mind when we talk of scientific (or for that matter, artistic) creativity. In that case, novel behaviors are refering to the cumulated set of previous productions in a wide cultural community. There is very little chance that an individual will contribute some novel behavior if he or she has not mastered, or has no thorough knowledge of what has been done before. This is probably true of any creative contribution in the arts. It is certainly true of any novelty in science, where no significant contribution has been recorded from an individual ignorant of the field. This is to say that information, training in basic know-how and basic knowledge, possibly to a point where many

things are automatized, are prerequisite for original productions. This would be enough to recommend teaching scientific knowledge as an important aspect of training future creative scientists. How to teach it is another question, that we shall consider later.

If it is assumed that creative behavior is a product of some inborn endowment or of a genuine exploitation by an individual of its intellectual gifts, then teaching - and learning - would be limited to the transmission of the established knowledge and methods currently in use. This view is based on a persistent believe that learning and consequently teaching (it makes no sense to teach what cannot be learned) concerns only repetitive, stereotyped behaviors, as captured in expressions like rote learning or conditioning. The psychology of learning would apply to those aspects of school education that are unproductive and coercitive. School education, as that belief goes, should look for inspiration in other fields of psychology, possibly psychology of intelligence, cognitive psychology or some brands of so called humanistic psychology of individual achievement. This states of affairs is bound to a misrepresentation of the psychology of learning, the causes of which can be traced, for a part, in historical aspects of the psychology of learning itself. Discussion of this point would take us far beyond the scope of the present paper. As a matter of illustration, and in connection with the argument developed below, let us just mention two elements responsible for that misrepresentation.

(1) The psychology of learning has long been associated with a stimulus-response psychology, that is to say a mechanistic reduction of an organism's behavior to a purely passive role.

(2) Learning psychologists seem to have been interested more, in the last 50 years or so, in how simple responses can be maintained - in an apparently stereotyped manner - rather than in how new responses emerge. The emphasis has been on the stabilization of what has been acquired rather than on acquisition itself.

If we look at learning in a different way, we shall get to an approach where psychology of learning on one hand and psychology of intelligence or creativity on the other are no longer in conflict - as is, paradoxically, the case today - but are complementary to each other. In the applied field of education we shall be able to combine in one coherent framework the assignement to teach, i.e. get the student to learn, and to develop creative students - that is students who produce novel behavior in their field of expertise (see also Richelle, 1986).

*

* *

Learning processes are best understood in terms of an analogy with biological evolution. The latter is typically a process of change, that has produced throughout millions of years and is still producing an impressive number of novel forms. These are not, in a strict sense, predictable. They are the result of a peculiar kind of causal relation : some variations are fixed by selective pressure. The origins of variations have little, if anything to do wilth the nature of selective factors at work. They are mutagenic accidents, or fortuitous by-products of sexual reproduction. Chance is the

key word here. That is not to say that variations are without causes, but that the factors causing them are not related with their survival value as revealed afterwards, when selection has retained them.

The analogy was explicitly and abundantly used by Popper, among others, as rightly pointed out by Jacques Monod in his introduction to the French edition (1978) of The logic of Scientific Discovery : " Conjecture and refutation play in the development of knowledge the same logical role (as sources of information) as mutation and selection, respectively, in the evolution of the living world. And if natural selection has, in the living world, been able to build the mammals' eye or the brain of Homo sapiens, why would selection of ideas not have been able, in its own realm, to build the Darwinian theory or Einstein's theory ?".

The analogy between the process of biological evolution and scientific discovery is pervasive in Popper's works. It is most explicitly stated in Objective Knowledge, subtitled "An evolutionary approach". Especially relevant to my argument is Popper's characterization of the growth of knowledge as a special case of learning : "The growth of knowledge - or the learning process (italic mines) - is not a repetitive or a cumulative process but one of error-elimination. It is Darwinian selection, rather than Lamarckian instruction" (p. 144). "All this may be expressed by saying that the growth of our knowledge is the result of a process closely ressembling what Darwin called "Natural selection"; that is the natural selection of hypotheses : our knowledge consists, at every moment , of those hypotheses which have shown their *(comparative)* fitness by surviving so far in their struggle for existence; a competitive struggle which eliminates those hypotheses which are unfit." (p. 261).

Popper goes on by framing this view of the evolution of scientific knowledge in the general view of the development of knowledge - or learning - in living systems : "This interpretation may be applied to animal knowledge, pre-scientific knowledge, and to scientific knowledge." He further insists on the status of the analogy : "This statement of the situation is meant to describe how knowledge really grows. It is not meant metaphorically , though of course it makes use of metaphores... From the amoeba to Einstein, the growth of knowledge is always the same.... (p. 261).

In view of these, and many similar statements, reflecting not an incidental idea but a central tenet in Popper's thinking, it is all the more surprizing that Popper does not mention the close similarity between his theory and Piaget's epistemological theory, not to speak of Skinner's conception of learning. Piaget is well-known (and had been known for sometime at the time Objective Knowledge was published, 1978) for his unifying theory of knowledge, involving basically similar mechanisms from elementary biological forms to the highest achievements of human logics, as well as obviously different levels of complexity. Though it had been in germ in his early theoretical writings, Skinner elaborated the evolutionary analogy later in his career but he had already done so in Science and Human Behavior (1953), Contingencies of Reinforcement (1969) and About behaviorism (1974), (voir Richelle, 1987). As I have noted about Piaget and Skinner (Richelle, 1976), influential theorists often seem to ignore each other, and overlook significant convergences between their own and others' views. This is an interesting problem for the psychology of scientific activity.

To sum up, the evolutionnary analogy is equally appropriate to account for the rat finding his way in a maze, for the pigeon learning to peck a key successfully to obtain a food reward, for the chimpanzee discovering a solution to a practical problem, for the child getting through a school assignement or solving a survival situation in the slum of a great city and for the scientist carrying out experiments in the laboratory. In all of these, and other cases, there is elimination of unsuccessfull behaviors, there is selection of (possibly temporarily) adaptive activities by their consequences. This is not to say that there are no important differences between pigeons, rats, chimpanzees, children and scientists in term of structural complexity of their respective activities, but we can leave that out for the moment. We shall assume that when an individual organism is learning something - that is, is being changed as a result of interaction with its environment - a mechanism is at work which is analogical, at the scale of the individual, to the mechanism of biological evolution at the scale of the species. If the analogy is to be taken seriously, we must identify the consequences that make for the selective pressure exerted by the environment as well as the variations that provide the raw material upon which selection is to operate. Learning psychologists have been spending much time and ingenuity in describing consequences (in the Skinnerian school, this endeavour has been represented by the thorough study of so called contingencies of reinforcement). For reasons which need not be commented upon here, they have widely neglected the study of the sources and of the nature of behavioral variations.

There has been, however, a few exceptions to that neglect. Experimenters who did not address themselves specifically to the problem of variation have made casual observations, or collected experimental data that revealed relevant afterwards . More recently, systematic research has been carried out that pave the way for an extensive analysis. We shall not enter the technicalities of these researches but shall only describe a few simple examples, conveying the general spirit.

Let us take a very simple motor response such as the well-known lever-pressing of a rat in a conditioning chamber. Some positive consequence will follow any motor response sufficient in strength to activate the mechanical device. This leaves a number of physical dimensions unspecified : beyond the minimum force required, responses can vary in strength, they can vary in duration, etc. To what extend, and under which conditions, will the subject make use of the freedom given to him to vary his responses ? Simple experiments have shown that, in the absence of any restrictions, the animal will make use of that freedom, and exhibit a wide range of variability (see Boulanger et al., 1987).

Another simple case consists in arranging the situation so that responses can be varied in space, for instance by providing several levels instead of one, or by providing a pecking-key extending over ten centimeters rather that limited to a small disk, one centimeter in diameter. Monkeys offered several levers will make use of all of them under some contingencies, but limit themselves to one single lever under other contingencies. Pigeons exposed to a wide key will sparse their pecks over a wide range, under some contingencies, while sticking at a limited surface under other conditions.

Other simple observations indicate a trend toward variation in animals, otherwise duly rewarded for their behavior. In situations where two levers are available to a rat, and are made equally efficient, the subject will more often than not tend to shift from one lever to the other, even when he has been rewarded on the first lever. This behavior, called win and shift as opposed to win and stay, reveals a propensity to change from a response in spite of its having been reinforced.

In an elementary situation, time to run from a start point to the end of a straight alley is often used as a measure of learning. Running time decreases with training to an asymptotic value. When administered with some drugs, such as alcohol or amphetamines, rats showed running-times below that value. Paradoxically, the drug seems to improve learning. A closer look however, reveals that non-drugged rats, at the peak of their performances, still spend some time exploring the alley - doing something else than just running straight -. Drugged rats do no longer display that exploratory activity, they are rigidly doing what they are rewarded for. Learning is not improved : variability is reduced.

These and similar data suggest that organisms behave, to some extend, as generators of variability - and that their capacities for learning might be a function of their potentialities for variation. This hypothesis is akin with what is known from the study of exploratory activities and playing behaviors as well as with quantitative analysis of foraging behavior in various species.

Getting one step further, we come closer to situations classically described as problem solving tasks. Suppose there are 20 different ways to get the same, successful result. Will a subject adopt one of these ways, or use several or all of them ? Will the choice be a different one depending upon the species, the age, the history of the subject ? Can the choice be modified, for instance, by increasing the pay-off of being more variable or less variable ?

Experiments addressing these questions have been carried out , after an initial paradigm designed by Vogel and Anau (1973), by B. Schwartz (1981, 1985) in the U.S. and by a group of researchers in our laboratory. We shall not describe these results, because this would take us into many technical questions and also because they would not, at the time being, lead to a general picture that would make sense to a non-specialized reader. Suffice it to allude to data related to the last of the questions formulated above, namely - in slightly different terms - "is behavioral variability itself amenable to control by consequences, as any other learnable behavior ? In other words, can selection operate on variability itself ?".

Subjects, animals and human, have been submitted to an experimental condition in which reward is obtained for a given " solution " (here a sequence of responses) provided that it differs from the just preceeding solution, or from the n preceeding solutions. Producing a solution different from the just preceeding one reveals impossible, or extremely difficult for pigeons ; rats are slightly better at that and humans can manage to produce " novelty" as defined by reference to a larger set of preceeding responses. This might simply reflect differences in mnemonic capacities, but it is, at first sight, quite plausible to think of behavioral variability in that context as related to memory. (Just as a scientist has to keep record of the hypotheses he has already tested and eventually falsified).

The idea of rewarding an organism for variation has been put to work by Pryor et al. (1969). The authors undertook to train sea porpoises for producing bits of motor behavior that were novel, i.e. not yet emitted before in the experimental sessions. Novel behaviors were rewarded by fish; repetitive behavior went unrewarded. The subjects exhibited a wide range of different activities, some of which had been commonly observed before, some of which had not and reminded of behavior typical of some neighbour species.

In a series of experiments performed in our laboratory a few years ago, (Richelle and Botson, 1974) children were trained to solve practical problems by using materials in unusual ways, by destructuring and recombining objects and pieces of objects. That training induced flexibility of behaviors not observed in control subjects, and it transfered to somewhat different situations used as post-tests.

Though unsufficient to provide general theoretical framework for the place of variation in learning, these preliminary data and researches suffice to make it clear that behavioral variability can be looked at within the framework of general learning theory and can indeed be induced by resorting to well-known learning/teaching mechanisms. We need not build distinct, mutually exclusive categories, one for learning (and teaching), another one for creativity.

Looking at learning/teaching in that way of course changes something important in a traditional approach to school education. Teaching should provide numerous opportunities for variation. Teaching basic knowledge that is needed to build upon, especially in science, should be closely linked with training in variability - call it, if you like, divergent thinking. Though it does not make sense to cover again all the steps that led to present knowledge, it is probably essential that the student to whom such knowledge is transmitted gets trained to the sort of process by which errors were eliminated. If we want to start science learning early in development, this cannot be done at a purely abstract, symbolic and retrospective level. It must, litterally, be acted by the young science pupils.

This brings us to another dimension of psychology in the science classroom. It is by no means a new one, but it needs to be reminded because the Zeitgeist might tend to put it aside. We owe to Piaget the central idea that knowledge is rooted in action. What eventually develops in the more elaborate formal discourse, such as logics and mathematics or theoretical physics, was initially experienced in simple sensory-motor coordinations. Contemporary cognitive psychology, emphasizing the processes by which information is captured and processed, has minimized the role of action in the construction of knowledge. No one would deny the important and potential usefulness of cognitive psychology in education, but teachers should be warned against the risk of reinstating a passive subject - possibly actively treating information but without acting on the world around him. The active approach to science education is widely adopted by those who design interactive science museums and exhibitions.

The view of learning that has been eschewed here is perfectly compatible with the constructivist developmental theory of Piaget, as well as with most contemporary approaches to intelligence. It is by no means unconciliable with the current concerns of cognitive psychology. Finally, it provides for a general conception in which creative behavior is in continuity with other , more elementary forms of behavioral

changes. Such a conception is in lines with respected tradition in scientific circles, such as Popper's views on the nature of scientific discovery, that has been mentioned above.

Teachers which make the effort to look for inspiration in psychology are exposed to a much less harmonious picture . Learning psychology, Piaget's developmentalism, various brands of psychology of intelligence, psychology of creativity, cognitive psychology and so on are generally presented as totally conflicting schools of thought; some of them are said to be completely outdated, supplanted by others, the survival of which makes no doubt for their followers. This state of affairs reflects the persistence in psychology of a philosophical not to say an ideological twist, that will hopefully disappear as psychology ripens with age.

In the meantime it makes it difficult for the well-disposed teacher to make a choice, and find his way out. Eventually, he or she might give up all of psychology, with the conviction that there is nothing to learn from such contradictions.

It is hoped that this brief discussion will encourage a more positive stand.

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L'ART ET LA SCIENCE DE L'ENSEIGNEMENT

Hommage à Gilbert De Landsheere

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Apprentissage et enseignement. Réflexion sur une complémentarité

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Enseignement et apprentissage ne sont que les deux faces d'une même chose. C'est là une vérité de bon sens. Nul n'enseigne sans l'intention, ou l'espoir, que l'élève apprenne Si l'on peut définir dans quelles conditions un organisme apprend, il semblerait que l'on soit en mesure de préciser comment il faut enseigner. Pourtant, le spectacle des systèmes scolaires contemporains, où l'échec tient une place inquiétante, ne parait pas confirmer cette étroite liaison, à première vue évidente, entre apprentissage et enseignement. Peut-être cela vient-il de ce que nous n'avons rien compris encore à l'apprentissage, et par conséquent que nous nous trouvons dans l'impossibilité d'en déduire les meilleures modalités d'enseignement. L'enseignant se bornerait, dans ce cas, à accomplir quelque rituel au rapport très incertain avec les conduites et les savoirs que l'on espère voir s'installer chez les élèves. Dans sa forme la plus extrême, cette éventualité correspondrait à la faillite de la psychologie de l'apprentissage. Il se pourrait aussi que, notre savoir sur l'apprentissage n'étant pas négligeable, on n'ait pas réussi à en tirer parti dans la mise en place des conduites d'enseignement adéquates, pour des raisons qui relèveraient de la communication entre les domaines, ou, d'une façon plus classique et plus générale, de l'articulation des données de la recherche fondamentale à l'application. Enfin, peut-être voit-on très bien, sachant comment on apprend, com-

ment il faut enseigner, mais s'en trouve-t-on empêché par toutes sortes de circonstances étrangères au processus d'enseignement-apprentissage proprement dit, et qui relèvent des facteurs sociologiques, économiques ou idéologiques auxquels n'échappent pas les entreprises éducatives.

Nous retrouvons là trois thèmes de débat assez courants, pour ne pas dire traditionnels, dans les milieux pédagogiques, trois arguments que l'on pourrait reformuler de la manière suivante :

1. Les sciences psychologiques, et en particulier la psychologie de l'apprentissage, n'offrent rien qui soit de nature à éclairer l'enseignant sur ce qu'il a à faire. Elles sont vides, ou hors de propos.
2. En dépit d'une convergence apparente des problèmes rencontrés et des connaissances solides, en principe utilisables, de la psychologie, psychologie et pédagogie n'ont toujours pas réussi à opérer leur jonction.
3. La jonction s'est faite, au niveau théorique, mais son actualisation est tenue en échec pour des raisons auxquelles ni la psychologie ni la pédagogie ne peuvent rien; il est utopique et vain de concevoir l'enseignement comme un domaine d'application de la psychologie de l'apprentissage.

Sans doute aucune de ces trois propositions ne décrit-elle à elle seule la réalité. On y trouve plutôt un peu des trois en des proportions variables, de telle sorte qu'il serait plus nuancé de dire : les apports, encore très fragmentaires, de la psychologie sont partiellement intégrés par les enseignants qui malheureusement ne peuvent pas toujours en tirer tout le profit qu'ils voudraient parce que des facteurs extérieurs interfèrent avec leur action.

Il n'est cependant pas sans intérêt de partir de propositions distinctes, malgré leur aspect caricatural, d'une part parce que cela nous aidera à mettre de l'ordre dans notre réflexion, d'autre part parce que les discours sur l'enseignement se présentent encore très fréquemment sous cette forme.

1. FAUT-IL EVACUER LA PSYCHOLOGIE DE L'APPRENTISSAGE ?

La psychologie, et plus particulièrement la psychologie de l'apprentissage, s'est-elle fourvoyée, ou n'a-t-elle élaboré à partir de données empiriques artificielles que des modèles théoriques inutilisables dans le champ éducatif ? Si c'est le cas, il serait non

seulement vain de vouloir les y faire entrer, mais ce pourrait être néfaste. L'argument revient souvent, qui veut que la psychologie étant à côté de la question, ou étant trop peu développée, toute tentative pour s'en servir de guide dans l'enseignement ne peut mener qu'à la catastrophe, et qu'il vaut mieux s'en tenir à une pratique intuitive ancrée dans une tradition artisanale qui aurait fait ses preuves. En poussant à peine l'argument, on mettra au compte de la psychologie les difficultés que connaît aujourd'hui l'enseignement. Pour irritante que soit cette mise en cause pour le psychologue, elle ne le dispense pas de s'interroger sur ce qui pourrait la fonder.

Les psychologies de l'apprentissage se sont longtemps développées dans le cadre du behaviorisme au départ de recherches expérimentales sur l'animal. L'extension à l'espèce humaine, et plus particulièrement au contexte éducationnel, des lois dégagées de l'expérimentation animale a suscité des protestations. « Sommes-nous des rats ? » a-t-on répliqué à Skinner, qui avait poussé plus loin qu'aucun de ses prédécesseurs les extrapolations du laboratoire à la vie de la classe ou de la société. Ceux, nombreux, que gênait une analyse qu'ils tenaient pour réductionniste, se sont trouvés confortés dans leur réaction par l'évolution des idées en psychologie. Au moment même où s'affinaient les transpositions de l'analyse expérimentale du comportement aux situations pratiques de l'éducation, le courant cognitiviste prenait le devant de la scène. Les origines et les ramifications du cognitivisme contemporain dépassent largement notre propos (Gardner, 1985).

Nous importe seulement ici la rupture catégorique proclamée par certaines de ses variantes par rapport à la tradition behavioriste. Celle-ci n'apparait pas comme une étape de l'évolution des sciences psychologiques, étape normalement dépassable, et peut-être dépassée : elle est présentée comme un véritable fourvoiement, voire une erreur épistémologique capitale sur l'objet même de la psychologie, le comportement ayant usurpé, en quelque sorte, la place de la vie mentale ou de l'esprit tout au long de ce que Bunge appelait la « longue et ennuyeuse nuit du behaviorisme » (Bunge, 1981). S'intéressant de préférence à des mécanismes réputés supérieurs — de la mémoire, du raisonnement, de l'attention, de la formation de concepts, etc. — le cognitivisme se présente d'emblée comme un substitut doublement acceptable à la psychologie de l'apprentissage discréditée : il s'occupe de l'organisme humain (même s'il existe un important courant de

psychologie cognitive animale [Griffin, 1981, 1985] et si, par ailleurs, des théories cognitives de l'apprentissage animal ont été proposées [Dickinson, 1980]) et il s'attaque à un niveau plus proche de celui qui concerne l'éducation scolaire que ne l'étaient les parcours de labyrinthes ou les picorages orientés des pigeons skinnériens. Certes, nombre de recherches expérimentales, menées dans le cadre du cognitivisme, portent sur des phénomènes d'apprentissage et, à ce titre, prolongent les acquisitions de la psychologie de l'apprentissage traditionnelle. Mais les formulations nouvelles qui s'en dégagent, comparées à ces dernières, déplacent singulièrement l'accent de l'interaction observable du sujet avec le milieu dans lequel s'organisent les conduites qu'il acquiert, vers l'élaboration interne d'objets mentaux divers, élaboration dont on concède volontiers au sujet l'initiative.

Pour les pédagogues globalement réticents à s'alimenter aux savoirs psychologiques, le destin récent des psychologies de l'apprentissage (du moins tel que le représente une version radicale du cognitivisme) offre une confirmation inespérée de leurs positions. Ils ne peuvent que se réjouir de s'être épargnés tout effort d'assimilation de ces domaines que l'on vient aujourd'hui, au sein des sciences psychologiques elles-mêmes, à récuser si brutalement. L'expérience les confortera dans leurs positions, et ils attendront dans la même humeur la fin inévitable du cognitivisme. Quant à ceux qui limitaient leurs réticences aux psychologies de l'apprentissage traditionnelles, ils accueilleront au contraire les nouveaux courants avec faveur.

Si nous nous sommes quelque peu étendu sur cet exemple, c'est qu'il illustre bien un problème constant dans les relations entre psychologie et pédagogie. La psychologie évolue, nous semble-t-il, à deux niveaux. Le premier, et c'est celui qui compte pour le développement scientifique, est celui de l'accumulation de connaissances, souvent limitées et ponctuelles, mais dérivées de données empiriques valides; connaissances qui sont exposées à s'inscrire dans des modèles explicatifs différents avec les progrès de la recherche, dont les insuffisances et les erreurs constituent le ferment même d'un dépassement perpétuel qui intègre pourtant une part de ce qui le précède. C'est là la démarche classique, et distinctive, de la science. A un second niveau, le discours théorique demeure, en psychologie, marqué de confrontations véhémentes, de ruptures tapageuses, d'excommunications sans nuance — affaire de style, de lutte de territoire, de disproportion entre

le champ du savoir vérifié et celui du savoir spéculatif, etc. Pour qui se situe à l'intérieur de la discipline et prend un peu de recul, il n'est pas difficile de faire la part des choses et de s'accommoder avec amusement de ce qui se passe au second niveau, pour autant que quelque chose continue de se passer au premier. Pour le pédagogue qui les perçoit de l'extérieur, les remous du second niveau prennent plus d'importance; il s'y fie dans les choix qu'il fait de son alimentation psychologique, et risque ainsi d'aligner son action pédagogique sur les idées les plus à la mode (mais qui passeront) et les plus extrêmes (et par là, les plus néfastes dans l'action si elles se révèlent un jour erronées).

La désaffection pour les apports de la psychologie de l'apprentissage qu'a réussi à provoquer un certain discours cognitiviste ressortissant au second niveau doit, à cet égard, inquiéter. L'approche behavioriste avait contribué à défendre, en pédagogie, un certain nombre d'exigences de nature à renouveler la recherche et à enrichir la pratique. Ainsi de la définition préalable des comportements que l'on se donne pour but d'installer — qui sous-tend en pédagogie la définition des objectifs —; avec son corollaire : la définition, en termes de comportement, de performances objectivables et non de compétences inférées. Ainsi encore de l'attention systématique aux comportements de l'organisme qui apprend *en cours* d'apprentissage (opposé à la seule prise en compte d'un état initial et d'un état final); de l'importance reconnue aux conséquences du comportement dans la mise en place des apprentissages (que l'on trouve implicitement à la base des recherches sur l'enseignant comme source de feedback et renforcements de natures diverses). Ainsi encore de la fragmentation raisonnée des conduites complexes à construire en fonction d'une logique des apprentissages du sujet plutôt que d'une logique de la matière (démarche qui avait guidé Skinner dans ses travaux de pionnier sur l'apprentissage programmé, et toujours présente, en son principe, dans les recherches actuelles sur l'enseignement assisté par ordinateur).

Tous ces efforts rigoureux pour décrire les comportements réels de l'élève, pour décrire de même ceux de l'enseignant, pour caractériser leurs interactions, pour cerner le réseau réciproque de conséquences positives et négatives, pour évaluer, par référence à des objectifs précis, l'état final atteint, sa stabilité dans le temps, sa « généralisabilité », etc., tous ces efforts auxquels, rappelons-le au passage, Gilbert De Landsheere et ses élèves ont

brillamment et obstinément contribué, il serait absurde d'y renoncer, d'en oublier le fruit parce qu'un autre *isme* a vu le jour. Que le cognitivisme ait, de son côté, des apports à faire à la pédagogie, cela est hors de doute. Mais il n'y a pas lieu, pour autant, de se débarrasser de tout ce que plus d'un demi-siècle de psychologie de l'apprentissage, de Thorndike à Skinner, avait apporté à l'éducation. La raison de cette tentation, il faut y être attentif, tient à ce que, sous le couvert du cognitivisme, retour peut être fait vers une confortable réhabilitation de l'esprit avec son double avantage pour le pédagogue : le mentalisme, qui le dispense d'analyser les conduites pour invoquer des explications internes, et la restitution à l'élève de la responsabilité de son apprentissage — non au sens où le sujet de Skinner apprend en fonction des conséquences de ses actes, mais où l'apprentissage dépend d'une élaboration interne par les mécanismes du traitement de l'information que l'enseignant peut fournir en nourriture, en *input*, mais qu'il ne peut vraiment contrôler.

Dans ce contexte, on ne peut manquer d'être frappé de voir resurgir, dans le langage beaucoup plus sophistiqué du cognitivisme, les vieux débats sur l'unité ou la fragmentation de l'esprit, qui opposent les partisans du *general problem solver* (Newell et Simon, 1972) à ceux de la « modularité » (Fodor, 1983) comme on se querellait jadis sur le facteur *g* et comme on n'a jamais totalement cessé de se quereller, dans les écoles, sur les vertus formatrices du latin ou, plus récemment, des mathematiques.

En bref, il ne s'agit pas de nier l'intérêt des travaux du cognitivisme actuel. Ils constituent sans doute pour les pédagogues une source d'informations exploitable, et rien n'exclut qu'ils aboutissent à l'élucidation des mécanismes du fonctionnement mental, peut-être moins rapidement que ne le proclament ceux qui s'y sont engagés. Que nous soyons désormais à un niveau de profondeur d'analyse inégalé ne justifie pas que l'on évacue les acquis antérieurs dont, jusqu'à nouvel ordre, la portée pratique demeure décisive. Les médecins n'ont pas, dans leur enthousiasme pour la biologie moléculaire, renoncé à se laver soigneusement les mains avant une opération. Nous suggérons que les pédagogues ne renoncent pas à analyser les comportements des élèves et des enseignants en termes de relation entre conduites et conséquences, de stimulus discriminatifs, d'événements positifs et aversifs, de renforcements, etc. même si un discours plus ésotérique se révèle aujourd'hui plus adapté à certains aspects de ce qui se passe dans la tête des élèves et des maitres.

Que le courant cognitiviste n'ait pas, jusqu'ici, proposé de conception claire des apprentissages peut donner lieu à débat entre spécialistes. Ce qui, d'un point de vue pratique, apparaît évident, c'est le clivage très marqué entre la sphère strictement *cognitive*, nettement privilégiée, et les autres domaines du fonctionnement psychologique, auxquels renvoient, en gros, les termes *affectif* et *motivationnel* (Le Ny, 1982 ; Richelle, 1987). Alors que la réalité éducationnelle, comme la réalité clinique, font à tout moment apparaître leur interdépendance, leur indissociabilité, la perspective cognitive consacre implicitement et explicitement la dissociation. On retrouve ici une nouvelle juxtaposition des approches qui tout au long de l'histoire des rapports entre psychologie et pédagogie a rendu difficile l'intégration par des pédagogues des apports de la psychologie.

2. APPRENTISSAGE ET DEVELOPPEMENT

Nous en venons ainsi à la seconde des trois propositions dont nous sommes parti et nous nous arrêtons un instant aux raisons qui font obstacle à la mise à profit des savoirs psychologiques en pédagogie. Les branches de la psychologie que leur objet désigne le plus naturellement comme les références obligées pour l'enseignement sont la psychologie de l'apprentissage d'une part, la psychologie du développement de l'autre. L'une comme l'autre se présentent comme des domaines anciens, très développés, riches aussi bien de données empiriques que de modèles théoriques de la psychologie scientifique. L'une comme l'autre affirment depuis leurs origines leur utilité potentielle dans l'éducation. Néanmoins, pour le grand désarroi des éducateurs, elles ont cheminé sur des voies parallèles et n'ont pas, jusqu'ici, véritablement réussi à se rejoindre. Les raisons sans doute en sont historiques. La psychologie de l'apprentissage, née aux Etats-Unis, a fourni pendant plus d'un demi-siècle ses assises au behaviorisme ; elle a privilégié la recherche sur l'animal, par commodité technique plus que par préoccupation comparative, avec l'ambition ou la prétention constante d'élaborer une psychologie générale de l'apprentissage. La psychologie du développement a des racines essentiellement européennes, a constitué ses savoirs empiriques à partir de recherches sur l'enfant humain, et malgré la diversité des théories qui ont vu le jour, est demeurée dominée par des conceptions théoriques qui voient dans l'ontogenèse le déroulement d'un pro-

gramme épigénétique se traduisant par un enchaînement de stades (Richelle, 1982).

Paradoxalement, la problématique épigénétique n'a guère intéressé les psychologues de l'apprentissage, non plus que les psychologues du développement ne se sont intéressés aux mécanismes d'apprentissage. L'ignorance mutuelle où se sont tenus Piaget et Skinner offre de cet état de choses l'illustration la plus surprenante pour quiconque s'interroge sur l'unité de la psychologie (Richelle, 1976). Mais on en trouverait de multiples indices à des niveaux moins prestigieux. Ainsi, sur un quart de siècle de publications, une revue spécialisée dans la perspective skinnérienne ne comporte aucun article centralement ou marginalement consacré à l'aspect développemental. En dépit de certains rapprochements amorcés depuis une douzaine d'années, il n'existe pas de théorie véritablement intégrée du développement et de l'apprentissage (ce qui s'en rapproche le plus se situe dans le champ très spécialisé de l'ontogenèse animale). Or, on pourrait penser que la phase de croissance où se réalisent tant d'acquisitions comportementales nouvelles doit attirer l'attention des spécialistes de l'apprentissage, comme les mécanismes d'apprentissage devraient présenter un intérêt pour les spécialistes du développement. Quelles que soient les justifications que le psychologue veut se donner pour les tenir séparés, apprentissage et développement s'imposent simultanément et conjointement à l'enseignant. La réalité éducationnelle ne souffre pas qu'on les dissocie. Que peut l'éducateur qui reçoit deux messages distincts, et souvent d'ailleurs contradictoires, sinon ouvertement hostiles l'un à l'autre ? Il n'est pas raisonnable de lui demander d'entreprendre les synthèses que les psychologues n'ont pas été capables de lui offrir. Il peut néanmoins jouer un rôle important pour acculer ces derniers à s'en préoccuper sérieusement.

S'ils ont pu s'en désintéresser si superbement, c'est sans doute faute de s'être laissés interroger, entre autres, par la réalité scolaire. Le projet de la psychologie développementale, plus particulièrement dans la ligne d'un Piaget, a été de décrire et de comprendre l'histoire naturelle du développement, non de procurer à l'école des prescriptions didactiques, si ce n'est par la répétition de la règle générale selon laquelle il n'est jamais inutile de bien connaître le niveau de l'élève pour lui prodiguer un enseignement adapté. Dans la perspective piagétienne classique, l'école ne peut guère jouer d'autre rôle que de fournir des contenus à des capa-

cités opératoires qui se développent de toute façon fort bien sans elle, si l'on en juge par l'universalité des étapes du développement cognitif. Les différences massives du contexte culturel peuvent éventuellement entraîner des décalages chronologiques, non des bouleversements séquentiels, mais il ne faut pas attacher trop d'importance aux variations somme toute mineures que pourraient entraîner le milieu particulier au sein d'une culture donnée, et par conséquent, les particularités de l'enseignement. On sait le temps qu'il a fallu avant que s'imposent à quelques chercheurs piagétiens, bien après les rares études inter-culturelles, les recherches comparatives en milieux socio-économiques variés. Quant aux recherches sur les facteurs liés aux modalités d'intervention de l'enseignant, elles sont encore rares (Crahay, 1984). Dans la perspective de la formation des enseignants et de l'exploitation qu'ils peuvent apprendre à faire de toutes les richesses de la psychologie développementale, elles présentent en principe un intérêt considérable. Mais elles ne tireront toute leur portée que d'une fusion avec les études qui prolongent par ailleurs les problématiques de la psychologie de l'apprentissage. Nous y reviendrons donc après avoir formulé quelques remarques sur ces dernières.

3. ELOGE DE LA VARIABILITE

Si la psychologie développementale a pu faire peu de cas de la fonction délibérément « instructrice » de l'enseignant - un peu comme l'éthologiste prête peu d'attention aux performances des animaux obtenues par domestication et dressage - la psychologie de l'apprentissage devrait, quant à elle, déboucher immanquablement sur des caractérisations claires des conduites souhaitées chez le bon enseignant. Or cela n'a généralement pas été le cas. Et pour comprendre pourquoi, il nous faut à nouveau faire ici un retour en arrière dans l'histoire de la psychologie. Outre qu'ils prirent souvent le parti de travailler sur l'animal, les spécialistes de l'apprentissage, en bons expérimentateurs qu'ils étaient, se sont attachés à analyser les acquisitions dans des situations rigoureusement contrôlées. Cela veut dire que les variables indépendantes dont ils ont cherché à cerner l'effet sur l'acquisition ont été choisies pour permettre ou faciliter leur contrôle. A cet égard, il va de soi que des variables purement physiques sont préférables à des variables sociales ; il est aisé de leur donner des valeurs constantes, ou de les manipuler sans laisser la moindre marge de

fluctuation. La structure d'un labyrinthe, la nature et l'intensité de stimuli discriminatifs intervenant dans un conditionnement, la force exigée par le levier réponse, les paramètres définissant un programme de renforcement, sont plus nets et plus rassurants que les caractéristiques fluctuantes d'un partenaire social. C'est la raison pour laquelle les recherches sur l'apprentissage vicariant ou imitatif et sur la facilitation sociale de l'apprentissage chez l'animal sont demeurées marginales et se révèlent, encore aujourd'hui, pleines de pièges. Le pédagogue qui jette son regard sur la psychologie de l'apprentissage n'y trouvera donc pas grand-chose sur les conduites de l'enseignant, qui représentent pourtant une portion importante des conditions qui président aux apprentissages scolaires. Il a fallu attendre les théories de l'apprentissage social (Bandura, 1976) pour que soit prise en compte, avec l'importance qui convient, la part que tiennent les partenaires sociaux.

Encore a-t-on souvent ambitionné de transposer sur l'enseignant l'invariance des facteurs physiques analysés en laboratoire. Cette invariance paraissait simplement dictée par les exigences expérimentales. En réalité, elle ressortissait plus profondément au parti-pris de mettre l'accent, dans l'étude de l'apprentissage, sur les régularités les plus immédiatement définissables. C'est ce que traduisaient bien les premières tentatives d'enseignement programmé proposées par Skinner. La machine à enseigner était destinée, entre autres, à pallier par sa constance de fonctionnement les variations et l'imprévisibilité inhérentes aux comportements des maîtres. Les conduites des élèves, de leur côté, devaient s'y construire en correspondance étroite avec la rigueur du programme, à la limite sans erreurs (Richelle, 1966). Il y avait là une réplique fidèle de l'assimilation qui fut faite si fréquemment entre apprentissage/conditionnement d'une part, stéréotypie/rigidité des conduites d'autre part. Il ne faut pas s'étonner qu'elle ait soulevé, il y a une trentaine d'années, une opposition quasi unanime dans les milieux scolaires. L'idée de la machine à enseigner aurait probablement rejoint le musée des petites inventions curieuses si ne l'avait relancée, presque aussitôt, et à un autre échelon d'efficacité, l'entrée en scène de l'ordinateur. Derrière le refus de « conditionner » les élèves, si souvent et ouvertement proclamé, et la réticence, fort compréhensible, à remplacer le maître, il y avait, moins explicite, une autre réaction de la part des enseignants : cette machine, qui se substituait à eux, faisait, prétendait-on, mieux qu'eux, dans sa programmation uniforme ; c'est donc qu'ils ne faisaient pas bien, que s'ils devaient s'amen-

der, ce devait être en ressemblant aux machines, donc en se conduisant comme elles de façon plus uniforme. Ce qui était en péril, c'était la diversité, la variation – d'un moment à l'autre chez un même maître, d'un maître à l'autre – bref, tout ce qui fait, aux yeux d'une tradition qui se nomme volontiers humaniste, l'irréductible individualité. Le même motif rend compte de la résistance aux recherches objectives sur les comportements de l'enseignant en classe : si l'on entreprend de les observer, puis de les décrire, c'est avec l'arrière-pensée de les changer, et sans doute dans le sens d'un alignement sur un modèle homogène (tableau qui se complique encore lorsque la recherche dévoile, en place de la richesse créatrice que l'on prétend préserver, une pauvreté de moyens dont la répétition stéréotypée n'a même pas l'excuse de l'efficacité).

Le problème doit être reposé, aujourd'hui, en termes nouveaux, qui présentent le double intérêt de faire droit à l'intuition des défenseurs de la diversité et de dédramatiser la mise en question, toujours difficile, de l'enseignant. Nous reviendrons dans un moment aux conduites de ce dernier, mais il nous faut, auparavant, pour situer le problème dans sa perspective théorique générale, nous tourner vers le sujet qui apprend.

L'apprentissage correspond à la mise en place de conduites dont les conséquences se révèlent positives (utiles, « adaptatives ») pour le sujet. Contrairement à une conception empiriste à laquelle on assimile souvent à tort la psychologie de l'apprentissage, le milieu n'est pas créateur ou producteur de conduites : il fournit le contexte dans lequel elles apparaissent, et les conditions qui opèrent le tri, la sélection. Pour que ce tri ait lieu, il faut qu'il y ait quelque chose à trier. Tout apprentissage présuppose donc des variations. Le modèle le plus suggestif pour rendre compte des apprentissages individuels est ainsi un modèle analogique qui nous renvoie au type de mécanisme à l'œuvre dans l'évolution biologique, où l'action sélective du milieu s'exerce sur les variations qu'offre le matériau génétique à l'échelle des populations. L'analyse des caractéristiques du milieu susceptibles d'opérer le tri devrait donc se compléter, ou mieux devrait être précédée, d'une analyse des variations et de leurs sources. Or cette dernière a été presque complètement négligée par les spécialistes de l'apprentissage. Les raisons de cette négligence sont multiples, et leur examen nous entraînerait dans des détails d'histoire de la discipline qui n'ont pas leur place ici. Qu'il suffise d'évoquer les pro-

grès des techniques de laboratoire, qui favorisèrent l'étude systématique des effets sur le comportement de conditions de milieu complexes et rigoureusement définies ; la tendance toujours présente en psychologie à établir d'abord la solidité scientifique là où il est le plus commode d'en faire la démonstration, face à la difficulté pratique et théorique de traiter des variations pour elles-mêmes. Il ne faut pas minimiser cette dernière difficulté. Les variations, qu'elles soient intra-individuelles ou inter-individuelles, ont généralement été envisagées par la psychologie scientifi que comme sous-produit de l'imperfection des conditions de recherche, qu'il convient soit d'éliminer, par des contrôles toujours plus rigoureux, soit de neutraliser, par la multiplication des mesures (avec l'espoir que si les variations surviennent aléatoirement en sens divers, elles s'annuleront réciproquement, la valeur centrale pouvant être retenue comme témoignant du phénomène étudié). Il n'est guère, pour avoir pris les variations pour constitutives du réel et objet spécifique d'étude, que la psychologie différentielle (pour ce qui est des variations inter-individuelles) et, pour ce qui concerne les variations intra-individuelles, la psychologie développementale « cycle de vie » (*life span*) récente.

L'étude des variations intra-individuelles demeure marginale et timide dans les secteurs spécialisés de la psychologie de l'apprentissage où il semblerait qu'elle doive tenir la première place. Quelques chercheurs isolés y ont porté attention au cours des quelque trente dernières années et quelques rares équipes se sont, plus récemment, attelées à la tâche. Tâche rendue possible, sur le plan technique, par l'évolution des outils de contrôle en temps réel des situations expérimentales, d'enregistrement et de traitement des données (le micro-ordinateur permet d'aborder concrètement des problèmes que les dispositifs automatisés de la génération précédente ne pouvaient maîtriser). Tâche encouragée, par ailleurs, au plan théorique, par la convergence de formulations, dans des disciplines très diverses, de la génétique (où la nature des mutations constitue une cible de recherche centrale) à la neurologie (que l'on songe à la théorie de la stabilisation sélective d'un Changeux) et jusqu'à la physico-chimie (voir les conceptions propagées, avec la fécondité que l'on sait, par Prigogine).

Pour nous en tenir, plus modestement, au domaine de la psychologie et à des champs voisins de la psychologie de l'apprentissage, on ne peut manquer de signaler la parenté de problématiques entre une psychologie de l'apprentissage qui fasse une place

de choix au thème des variations comportementales et diverses autres approches. Signalons en premier lieu l'idée développée par Lorenz (un Lorenz qui a singulièrement évolué, en un quart de siècle, quant à ses vues sur l'apprentissage chez l'animal) d'espèces à programme d'apprentissage plus ou moins « ouvert » : l'espèce à programme ouvert jouirait d'une palette plus riche de potentialités comportementales, toujours inscrite, cela va sans dire, dans les limites de contraintes spécifiques incontournables. Retenons, pour nous en resservir plus loin, l'explication fournie par Lorenz de cette différence entre espèces quant à l'ouverture de leur programme d'apprentissage : les espèces à programme fermé auraient évolué dans une niche écologique particulièrement stable, aux conditions homogènes, les espèces à programme ouvert au contraire auraient évolué dans des milieux instables et diversifiés. Cette flexibilité mise en place à travers l'évolution biologique devient à son tour facteur de survie dans des milieux se transformant de façon inédite. L'espèce humaine est, à cet égard, privilégiée (avec des risques non négligeables d'être victime de sa capacité à se forger de nouveaux milieux) comme, à un autre niveau, le rat (que Lorenz oppose, à titre d'exemple, au cheval).

La dialectique du développement proposée par Piaget, et particulièrement élaborée dans la dernière phase de sa carrière, fait elle aussi, avec la notion de déséquilibration, une place centrale aux variations, « variations novatrices » à l'œuvre d'un bout à l'autre du vivant, « du plan élémentaire des mutations au plan supérieur des théories scientifiques » (Piaget, 1974 ; voir à ce sujet Richelle, 1976).

D'un troisième côté, la psychologie de l'apprentissage rejoint ici l'étude des comportements exploratoires, comme celle des conduites ludiques, qui manifestent, les unes comme les autres, la tendance des systèmes vivants à entretenir à un certain niveau des activités dont la fonction n'apparaît pas immédiatement.

Variations intra-individuelles et surtout inter-individuelles se sont également imposées à ceux qui ont étudié dans le détail les conduites de solution de problème. Les stratégies auxquelles les sujets ont recours varient selon le problème abordé et, très largement, selon les sujets. L'origine de cette diversité est loin d'être élucidée. Qu'elle relève pour une part de dispositions « innées » ou « constitutionnelles », pour une autre part de l'histoire du sujet, n'enlève rien à son importance pour l'éducateur, qu'il

s'adresse directement à une classe ou qu'il mette au point un didacticiel, puisqu'il lui faudra porter son attention, plutôt qu'à une logique de la matière, à une logique non *du* sujet mais *des* sujets.

Nous pourrions poursuivre la liste des domaines de la psychologie contemporaine où l'on en est venu à s'intéresser aux variations pour elles-mêmes. Les exemples évoqués suffisent à indiquer l'élargissement que cette perspective implique pour la psychologie de l'apprentissage, avec la conséquence importante pour les enseignants qu'il n'y a plus de justification à la tenir pour dissociée de la psychologie de l'intelligence, du développement, de la créativité, etc.

Mais il nous faut revenir à présent à l'autre volet de la situation d'enseignement, à l'enseignant, dont nous disions plus haut qu'il avait pu craindre de voir étudiés ses comportements en classe dans le seul but de les modeler ensuite selon une norme rigide, de lui donner dans la situation scolaire une fonction aussi rigoureusement définie que celle des variables indépendantes d'une expérience d'apprentissage en laboratoire. Si, du côté du sujet qui apprend, les variations apparaissent comme essentielles à la dynamique des acquisitions, si, en d'autres mots, cultiver les potentialités d'apprentissage d'un organisme suppose que l'on préserve son registre de variations comportementales (voire qu'on l'élargisse), il devient évident que du côté de celui qui enseigne, on ne peut rechercher l'uniformité. Elle serait en effet antinomique à l'entretien de la variabilité chez l'élève. Nous reportant à la relation que Lorenz indiquait entre invariance du milieu et programme fermé au cours de la phylogenèse, on pourrait suggérer que la variabilité comportementale chez le sujet qui apprend a pour condition la variabilité dans les conduites de l'enseignant, dans la mesure où ce dernier représente une part essentielle du milieu destiné à installer des apprentissages. Cette prescription déplace radicalement l'accent dans l'étude des comportements des maîtres : on ne s'y fixera pas à en évaluer l'efficacité ponctuelle, par rapport à des objectifs limités, mais on visera à en caractériser la portée en tant qu'inducteurs de variations utiles aux apprentissages des élèves. Cette perspective présente l'avantage de n'impliquer aucune notion de « comportement idéal » chez le maître qui se prête à une étude de ses propres conduites. Il n'y a pas de « modèle normatif » à substituer aux imperfections constatées, mais plutôt recherche de l'apport personnel à la dynamique

des variations, et éventuellement recherche des moyens de l'amplifier.

A un plan plus général, les querelles de méthodes qui ont jalonné, comme autant de fléaux, l'histoire de l'enseignement, *perdent de leur signification, rien n'excluant que plusieurs méthodes coexistent*, non seulement pour répondre aux diversités individuelles, mais pour favoriser chez chaque élève la capacité de s'ajuster à la diversité des sollicitations du milieu.

Ce programme esquissé, il reste à s'interroger sur les démarches à mettre en œuvre pour, dans un premier temps, analyser sous l'angle de la variabilité les comportements de l'enseignant, puis, dans un second temps, définir la variabilité que l'on tiendrait pour souhaitable dans un projet pédagogique. Sur ce dernier point, une remarque s'impose : reconnaître l'importance de la variabilité n'entraîne pas que la situation idéale, pour provoquer des apprentissages, soit celle où le sujet serait confronté à des variations purement aléatoires. Tout apprentissage est organisation, et suppose une cohérence dans la structuration du milieu. A ce titre, les variations s'inscriront à l'intérieur de certaines marges. On sera naturellement amené, pour préciser ces dernières, à s'interroger sur les rapports entre variation d'une part et définition des objectifs et des moyens de les atteindre d'autre part, une question qui ne relève pas moins de la philosophie de l'éducation que de l'analyse scientifique.

Dans une perspective de recherche, c'est le premier point, l'analyse de la variabilité chez l'enseignant, qui doit retenir d'abord l'attention.

L'observation, directe ou différée, demeurant la seule méthode utilisable, il va de soi qu'elle devra porter simultanément sur un grand nombre de catégories de conduites et de paramètres, qu'il faudra traiter ensuite à l'aide de modèles propres à faire ressortir les caractéristiques dynamiques des variations. Un exemple élémentaire fera saisir le changement de niveau de l'analyse. Dans les premières études sur les comportements des enseignants, on estimait déjà précieux (et ce l'était en effet) de relever la fréquence de telle catégorie de comportements [par exemple, les fonctions d'organisation, d'imposition, de développement, etc. utilisées jadis par De Landsheere et Bayer (1969)]. Si l'on s'intéresse à cerner la variabilité, la fréquence d'un comportement à

elle seule n'apporte pas grand-chose ; il faut la caractériser dans ses relations avec la fréquence des comportements alternatifs (dans les deux registres du verbal et du non verbal) et en tenant compte de la dimension temporelle (ce qui appelle une analyse de type séquentiel) ; il faudrait aussi la rapporter aux particularités individuelles des élèves, à la spécificité des contextes (type de matière enseignée, forme de leçon, etc.).

La complexité de l'entreprise aurait de quoi faire reculer. Neanmoins, les progrès réalisés dans d'autres secteurs, quant au traitement des phénomènes de complexité comparable, incitent à s'engager dans cette direction. Il y faudra quelques moyens, et nous retombons dans la troisième des hypothèses formulées à notre point de départ. Ce type de démarche n'est pas de celles que l'on improvise, ni qui ait quelques chances d'aboutir à court terme. Elle pourrait cependant être, au-delà de l'occasion d'une meilleure intégration des savoirs psychologiques et des savoir-faire pédagogiques, la condition d'un dépassement des oscillations entre extrêmes dans la perpétuelle et stérile querelle des « anciens » et des « modernes » qui agite le monde de l'éducation.

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REVUE CRITIQUE

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VARIABILITÉ COMPORTEMENTALE ET CONDITIONNEMENT OPÉRANT CHEZ L'ANIMAL

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SUMMARY : Behavioral variability and operant conditioning in animals.

The purpose of this critical review of current knowledge in the field of animal behavioral variability within operant conditioning settings, is to pave the way of future research. The present review is organized around two main lines : 1) the influence of several variables on the spontaneous variability of the operant response and 2) the selective reinforcement of operant response variability. It is concluded that variation mechanisms have been studied much less than selection mechanisms (even if these mechanisms are complementary in theories of learning). Some results lead us to consider behavioral variability as an inherent dimension of behavior, sensitive to contingencies of reinforcement, just like any other dimension (e.g. response force or duration).

Key words : behavioral variability, operant conditioning, animal behavior.

La psychologie de l'apprentissage chez l'animal apparaît, comme le notait Gruber (1976), plus préoccupée de répétition des comportements acquis que de leur acquisition elle-même. Ainsi, l'activité opérante est généralement appréhendée à travers la reproduction stéréotypée d'une unité motrice élémentaire, attestant le contrôle exercé par les contin-

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gences de renforcement. Le terme de conditionnement en a pris, non seulement dans le grand public, mais parmi les psychologues non spécialisés en la matière, une connotation particulière : il s'y attache une notion de passivité du sujet soumis à des contraintes qui rendent sa conduite rigide. Contrairement aux activités de résolution de problème, où le sujet mettrait en œuvre ses véritables capacités adaptatives — ou, chez l'homme, aux activités créatives — le conditionnement passe pour un mécanisme qui, loin de servir l'adaptation du sujet, irait à son encontre, du moins dès que l'on dépasse le niveau du comportement très simple et le cadre particulier d'une situation expérimentale très artificielle.

Cette représentation du conditionnement est discutable, à double titre, car, d'une part, s'agissant d'un mécanisme d'apprentissage, on s'attendrait à ce que l'accent soit mis sur le changement, plutôt que sur la stabilisation des conduites, et d'autre part, on comprendrait mal, dans le cadre habituel de l'explication biologique, comment se serait mis en place un processus de modification des conduites de quelque importance et de quelque universalité qui ne soit, en règle générale, au service de l'adaptation. Elle ne s'accorde pas avec les formulations théoriques qui tentent de cerner les caractères dynamiques du mécanisme de conditionnement. Ces formulations ont recours à une analogie avec le mécanisme qui, à une autre échelle, celle de l'évolution des espèces, rend compte lui aussi de transformations et d'emergences de formes nouvelles (voir Skinner (1966) ; Plotkin (1982) ; Richelle (1983)). On sait que, dans le sillage de Darwin, la biologie reconnait dans l'évolution du vivant le fruit de la pression sélective du milieu s'exerçant sur le matériel génétique. La pression sélective ne créant rien, mais se bornant à trier, les formes nouvelles dépendent des variations du matériel génétique — variations dues aux mutations ou résultant de la recombinaison des gènes au sein des populations. Une théorie des changements biologiques se doit donc d'aborder ces variations, d'en cerner la nature et les sources, non moins que de préciser les processus de tri impliqués dans la rencontre de l'espèce avec sa niche écologique. Le modèle de l'évolution biologique, appliqué au développement des conduites de l'individu, tient, faut-il le rappeler, une place centrale dans la théorie constructiviste de Piaget (1967). Dans un autre contexte, Popper (1973) l'a explicitement utilisé pour rendre compte de l'évolution des connaissances. On le retrouve encore dans la théorie de la stabilisation sélective proposée par Changeux (1983) à propos de l'épigenèse des connexions neuronales dont on peut penser qu'elles renvoient, sur le plan des conduites, aux jeux conjugués du développement et de l'apprentissage.

Si l'analogie, appliquée au conditionnement, a quelque valeur, ne serait-ce qu'au niveau métaphorique, la psychologie de l'apprentissage devrait attacher une attention aussi grande au volet variation qu'au volet sélection du processus de conditionnement. Or pour des raisons que l'on trouvera discutées ailleurs (voir Richelle, 1983), l'étude des

variations a été largement négligée au profit de celle des contraintes sélectives. Si, au plan théorique, plusieurs auteurs ont attiré l'attention sur l'importance des variations (Skinner, 1966; Staddon et Simmelhag, 1971), l'analyse expérimentale n'a guère suivi. Quelques recherches pourtant font exception, qui attestent qu'aucun obstacle technique ne s'oppose à ce que le problème soit abordé et que quelques chercheurs en ont perçu la portée théorique. Elles méritent d'être synthétisées et discutées, dans le double but de susciter un intérêt pour une problématique qui recouvre, à nos yeux, la moitié à peine explorée du territoire de l'apprentissage, et de repenser cette dernière dans une théorie intégrée où les activités de résolution de problème, les productions créatives et l'activité exploratoire n'apparaissent plus comme distinctes voire opposées aux mécanismes d'apprentissage mais s'y articulant étroitement.

La revue qui suit se limite aux travaux portant sur les réponses opérantes chez l'animal. Il s'agit là d'une restriction délibérée du domaine étudié, que justifient d'une part les qualités de rigueur et d'élaboration des expériences sur l'animal, par rapport aux recherches comparables sur l'enfant ou l'adulte humain, d'autre part le souci de montrer que l'intérêt des variations concerne déjà clairement les apprentissages élémentaires chez l'animal et n'attend pas que l'on atteigne des niveaux supérieurs de complexité des conduites.

Les recherches présentées sont organisées autour de deux questions :

1 / Quelles variations présente, dans les marges autorisées par la définition que l'expérimentateur en a choisie, la réponse opérante, en fonction de divers facteurs, contingences de renforcement, histoire du sujet, etc. Nous parlerons à ce propos de variabilité spontanée en ce sens qu'elle n'est pas une condition requise pour l'obtention du renforcement.

2 / Est-il possible de renforcer sélectivement les variations d'une réponse opérante au même titre que tout autre aspect, force, localisation, amplitude, durée, etc. ? Ici la variabilité est requise.

La première question n'est pas sans rapport avec un problème soulevé par Skinner dans son article théorique classique (Skinner, 1935) où la notion de réponse opérante était définie comme une classe dont les membres — des réponses réellement produites et enregistrées — pouvaient varier pour autant qu'elles répondent au critère définissant la classe. Ainsi, l'appui sur un levier entraîne le renforcement si la force exercée atteint une valeur minimale ; au-delà de ce minimum, la force peut varier, comme peut varier d'autre part la durée, qui n'a pas été spécifiée dans la définition de la réponse efficace.

On traitera d'abord les réponses opérantes simples, pour examiner ensuite les réponses complexes, qui nous rapprochent des tâches de résolution de problème.

A. — VARIABILITÉ SPONTANÉE

1 / Réponses opérantes simples

C'est à Antonitis (1951) que l'on doit la première recherche sur la variabilité de la réponse opérante. La réponse dans cette étude pouvait varier quant à sa localisation — introduction du museau du rat en un point d'une fente horizontale de 50 cm. Dans des situations dites de renforcement continu (CRF : chaque réponse est renforcée), la variabilité, considérable en début d'apprentissage, diminue progressivement pour faire place, au fil des séances, à un comportement plus stéréotypé. Elle se manifeste à nouveau en situation d'extinction. Eckerman et Lanson (1969), dans une recherche comparable, présentent à leurs pigeons une clé-réponse longue de 20 cm, subdivisée en 10 zones. Ils confirment les résultats d'Antonitis, comme le font d'autres auteurs qui ont étudié la variabilité à propos d'autres dimensions de la réponse, telles que la durée (Millenson et Hurwitz, 1961 ; Margulies, 1961 ; Crow, 1978 ; Lachter et Corey, 1982), la force (Notterman, 1959), la latence (Stebbins, 1962), le travail — mesuré par le déplacement du levier — (Herrick, 1963, 1964 ; Herrick et Bromberger, 1965) et la topographie (Muenzinger, 1928).

En règle générale, lorsque les critères définissant la classe opérante autorisent des fourchettes de variation peu contraignantes, on observe que les réponses se stabilisent progressivement autour d'une valeur centrale, souvent différente d'un animal à l'autre. L'augmentation de la stéréotypie de la réponse, au fil de l'exposition au CRF, reflète le contrôle par le renforcement et est sans doute interprétable par la tendance au moindre effort (Herrick et Bromberger, 1965, par exemple) ou, de façon plus raffinée, en terme d'optimalisation du comportement (Notterman, 1959 ; Staddon, 1980, par exemple).

La variabilité réapparaissant en situation d'extinction — en fonction, entre autres, de la durée de l'entraînement en CRF (Thompson, Heistad et Palermo, 1963) — atteste la réversibilité du phénomène constaté en phase de conditionnement. La situation d'extinction ne se borne donc pas à réduire le débit des réponses, elle en augmente la variabilité.

D'autres recherches ont exploré les situations à renforcement intermittent, intermédiaires entre ces deux extrêmes que sont le renforcement continu et l'extinction. A l'exception des travaux de Herrnstein (1961), de Millenson, Hurwitz et Nixon (1961) et de Boren, Moersbaecher et Whyte (1978) — sur lesquels nous reviendrons —, on observe généralement une augmentation de la variabilité lors du passage du CRF au renforcement intermittent (Millenson et Hurwitz, 1961 ; Stebbins et Lanson, 1962 ; Herrick et Bromberger, 1965 ; Ferraro et Branch, 1968 ; Eckerman et Lanson, 1969 ; Lachter et Corey, 1982 ; Tremont, 1984).

Se pose ici la question de la relation entre le degré d'intermittence et la variabilité. On peut, avec Schoenfeld (1968), faire l'hypothèse qu'aux

périodes successives d'extinction inhérentes aux situations de renforcement intermittent, correspondrait une variabilité comportementale accrue, par rapport à celle que l'on observe en CRF. Par conséquent, le nombre de variantes renforcées de la classe opérante étant plus élevé, l'extinction sera prolongée, chaque variante devant être éteinte séparément. Cette hypothèse implique que si les renforcements se font plus rares (si le degré d'intermittence augmente), la variabilité augmente. C'est ce que confirment Tremont (1984), travaillant sur les intervalles inter-réponses (IRT), et Boren *et al.* (1978), sur la localisation (choix entre 6 leviers). Par contre, les résultats de Millenson et Hurwitz (1961), sur la durée, de Tremont (1984), sur la force, et d'Eckerman et Lanson (1969), sur la localisation, vont dans le sens opposé. Ces données contradictoires s'expliquent peut-être par trois variables : le contexte comportemental, la dimension de la réponse mesurée et le type de programme de renforcement en cours (programme à composante temporelle ou programme à proportion).

— Il y a lieu de considérer le contexte comportemental dans lequel la réponse opérante apparaît. En effet, la conduite est un phénomène à caractère continu (Skinner, 1953 ; Schoenfeld et Farmer, 1970), et ce sont seulement des exigences méthodologiques qui imposent d'isoler des unités arbitraires du « flux comportemental » ininterrompu. Les autres comportements de l'organisme interagissent avec la réponse opérante et peuvent donc influencer l'expression de sa variabilité. Une étude de Herrnstein (1961) illustre ce point et mérite un examen détaillé. Herrnstein constate, à l'encontre d'autres chercheurs, qu'un programme de renforcement intermittent à composante temporelle (VI 3 mn) entraîne une diminution de la variabilité dans la localisation de la réponse, par rapport à la variabilité observée précédemment en CRF. Dans son dispositif expérimental — une cage de conditionnement pour pigeons —, une longue clé-réponse est placée sur une paroi et le distributeur de renforcements sur la paroi opposée. En CRF, les pigeons donnent plus de coups de bec aux extrémités de la clé et cette préférence s'accentue dès la première séance en VI 3 mn (comportements très stéréotypés). Ferraro et Branch (1968), et Eckerman et Lanson (1969) reproduisent cette expérience, mais en plaçant le distributeur de renforcements sous le centre de la clé-réponse. Ils observent, à l'opposé de Herrnstein, une forte augmentation de la variabilité lors du passage au renforcement intermittent, conformément aux données des autres auteurs. On peut supposer que, dans l'expérience de Herrnstein, d'autres comportements que ceux pris en compte par l'expérimentateur, tels les déplacements entre distributeur de renforcements et dispositif-réponse, auraient interagi avec la réponse opérante et influencé la variabilité de cette dimension.

— Cette variable « contexte comportemental » paraît en interaction avec la variable « dimension de la réponse ». Tremont (1984) étudie cette interaction en mesurant, d'une part, la variabilité de la force de la

réponse — dimension qu'il considère comme peu altérable par le voisinage d'autres comportements — et, d'autre part, la variabilité des intervalles inter-réponses — dimension supposée plus vulnérable à l'interférence des comportements apparaissant entre les réponses opérantes. En augmentant l'intermittence d'un programme à intervalles variables, il obtient un accroissement de la variabilité des IRT, mais non de celle de la force de la réponse. L'importance du flux comportemental, abondamment démontrée dans d'autres perspectives, doit inciter, ici aussi, les chercheurs à mieux contrôler et mesurer les comportements autres que la réponse opérante et susceptibles d'en influencer la variabilité.

— S'agissant du type de programme de renforcement intermittent en cours, la plupart des recherches utilisant des programmes à composante temporelle montrent une augmentation de la variabilité comportementale lors du passage du CRF au renforcement intermittent (Ferraro et Branch (1968), Eckerman et Lanson (1969), Boren *et al.* (1978), pour la localisation de la réponse ; Tremont (1984), pour les intervalles inter-réponses ; Millenson *et al.* (1961), Schwartz et Williams (1972), pour la durée de la réponse). Quant aux recherches utilisant des programmes de renforcement intermittent à proportion, certaines montrent une augmentation durable de la variabilité comportementale (Herrick, 1965 ; Herrick et Bromberger, 1965 ; Schwartz et Williams, 1972), d'autres une augmentation temporaire (Schaeffer et Steinhorst, 1959) et d'autres, enfin, n'obtiennent pas d'augmentation (Millenson *et al.*, 1961, Boren *et al.*, 1978). *Boren et al. (1978) comparent, plus spécifiquement, les programmes* à intervalles fixes (FI) et les programmes à proportion fixe (FR). Ils étudient la localisation de la réponse sur six leviers fonctionnellement semblables, chez des singes soumis à différentes valeurs de FR et de FI. Les valeurs du FI sont choisies sur la base des résultats obtenus en FR, afin d'apparier ces programmes en terme du degré d'intermittence *(yoked control design)*. En FR, la stéréotypie de la réponse — mesurée par le nombre de changements de leviers — est presque maximale pour toutes les valeurs envisagées (1 à 400), alors qu'en FI, la variabilité de la localisation est fonction du degré de l'intermittence. Zeiler (1968) observe le même phénomène en FR avec des pigeons. Une explication possible des différences entre les types de programme intermittent se base sur la nature de l'organisation des réponses qu'ils entraînent. En programme à proportion, le taux de renforcement obtenu est fonction du débit des réponses, qui se comportent comme des unités fonctionnelles (Zeiler, 1977), avec une variabilité minimale. En programme à composante temporelle, le taux de renforcement est, par contre, pratiquement indépendant du taux de réponse.

2 / Réponses complexes

Une réponse complexe est constituée de réponses simples, identiques ou non, émises successivement. Chaque réponse simple produit les conditions pour la réponse simple suivante. Les situations proposées pour étudier la variabilité des réponses complexes peuvent être résolues par plusieurs séquences correctes de réponses simples.

Une tâche de ce type a été mise au point par Vogel et Annau (1973) pour les pigeons. Le matériel se compose d'une cage opérante comprenant une matrice de 4 × 4 lampes, deux clés-réponse et un distributeur de grains. La réponse exigée est de trois coups de bec sur chaque clé-réponse, dans n'importe quel ordre. Au début de chaque essai, la lampe du coin supérieur gauche de la matrice s'allume. Un coup de bec sur une clé-réponse provoque le déplacement de la lumière d'une position vers la droite, un coup de bec sur l'autre clé-réponse déplace la lumière d'une position vers le bas. A la fin des six appuis requis, la lumière a atteint la lampe du coin inférieur droit de la matrice et le renforcement est délivré. Un quatrième appui sur l'une ou l'autre clé des deux clés-réponse termine l'essai sans renforcement. Vingt séquences différentes conduisent au renforcement. La même tâche a été utilisée par Perikel (1982) avec des rats. Schwartz (1980, 1981 *a*) a étudié l'influence du renforcement continu et de l'extinction sur l'établissement et le maintien des séquences de réponses émises par des pigeons, en utilisant une version légèrement modifiée de la tâche de Vogel et Annau (matrice de 5 × 5 lampes et 70 séquences correctes possibles).

Quelles que soient la tâche utilisée et l'espèce concernée, on constate, en effet, une diminution importante de la variabilité des séquences de réponses et l'apparition d'une séquence dominante (elle apparaît dans la majorité des essais). Pisacreta (1982 *a*, 1982 *b*) confirme ces résultats avec une tâche permettant un grand nombre de séquences correctes (les pigeons doivent éteindre des matrices lumineuses de 6 à 9 clés-réponse, en donnant un coup de bec sur chaque clé, dans n'importe quel ordre).

En situation d'extinction, la variabilité des séquences augmente, du moins si l'exposition préalable au conditionnement n'a pas été trop prolongée (20 sessions de 50 essais). Par contre, la stéréotypie persiste chez les pigeons dont l'entraînement a été plus intensif (50 séances de 50 essais) (Schwartz, 1980, 1981 *a*). Ces résultats suggèrent que, sous certaines conditions, les patterns de réponses acquis deviennent fonctionnellement intégrés. Ils se transforment en unités stéréotypées et se comportent tels des « blocs » insécables, peu sensibles à des modifications environnementales ultérieures. D'autres données vont dans le sens de cette hypothèse :

— une interruption des séances d'entraînement durant soixante jours n'influence ni la performance, ni la variabilité des séquences lorsqu'on

replace les pigeons dans la situation d'entraînement (Schwartz et Reilly, 1985) ;

— si des pigeons préentraînés ne disposent plus des indices lumineux (lampes éteintes), l'augmentation de la variabilité n'est que temporaire et la séquence dominante développée antérieurement ne tarde pas à réapparaître (Schwartz, 1981 *b*) ;

— si on envisage les séquences comme des réponses individuelles, les données obtenues avec des pigeons préentraînés soumis à des programmes multiples ou concurrents sont conformes aux comportements observés dans les études impliquant des réponses simples (Schwartz, 1986) ;

— si l'on considère que l'intermittence du renforcement est assimilable à une succession de périodes d'extinction, on peut prévoir que le renforcement intermittent aura des effets similaires sur la variabilité des séquences, à ceux manifestés en extinction. Schwartz (1982 *b*) place des pigeons préentraînés en FI et en FR. Il ne constate aucune augmentation de la variabilité des séquences. Les effets de ces programmes se marquent uniquement sur le temps de latence (temps séparant le début de l'essai du premier coup de bec de la séquence) et non sur le temps séparant les coups de bec, à l'intérieur de la séquence.

Ces résultats semblent donc confirmer que la séquence n'est pas constituée par une simple juxtaposition de coups de bec, mais qu'elle forme une unité organisée, avec une structure interne. Une étude de Schwartz (1985) suggère que cette organisation est de type hiérarchique, plutôt que sous forme de chaîne de réponses.

Le caractère, homogène ou non, des réponses qui composent les séquences est susceptible d'influencer l'intégration des réponses en unités (Schwartz, 1980, 1982 *a*, 1982 *b*, 1985), ainsi que le maintien des séquences en extinction. Peu d'études expérimentales ont tenté d'analyser les effets de différentes contingences de renforcement sur la variabilité de séquences de comportements hétérogènes (succession de réponses topographiquement différentes). Les travaux de Millenson *et al.* (1961) constituent une exception à cet égard. Ces auteurs ont conditionné des rats à émettre une séquence de comportements différents (appui sur un levier suivi du déplacement de l'animal et de l'introduction du museau dans l'orifice de la cage contenant le renforcement). En renforcement continu, l'animal émet des séquences de comportements tout à fait stéréotypées. En extinction, on observe une disparition de cette stéréotypie et une modification du pattern temporel des différents comportements.

B. — EFFETS DE VARIABLES PSYCHOPHYSIOLOGIQUES ET DES STIMULATIONS AVERSIVES SUR LA VARIABILITÉ DE LA RÉPONSE

Plusieurs auteurs ont étudié l'influence de variables psychophysiologiques sur la variabilité du comportement : effets de la privation alimentaire (Elliott, 1934 ; De Valois, 1954 ; Carlton, 1962 ; McSweeney, 1974) ; de la quantité du renforcement (Carlton, 1962 ; Stebbins, 1962) ; de l'alcool ; des drogues et des lésions cérébrales (Devenport, 1983). Nous renvoyons le lecteur à Devenport (1983) pour une information complète à ce sujet. Signalons cependant que l'ensemble de ces recherches montre que la variabilité comportementale est d'autant plus importante que l'organisme est proche de son état normal (absence de privation, de substances toxiques, de lésions cérébrales). Il semble dès lors regrettable que toutes les recherches recensées étudient la variabilité comportementale chez des animaux affamés.

Les études relatives à l'influence des stimulations aversives sur la variabilité sont rares (Hamilton et Krechevsky, 1933 ; Everall, 1935 ; Maier et Klee, 1943 ; De Valois, 1954 ; Ferraro et Hayes, 1967). De plus, leurs *différences méthodologiques ne permettent aucune généralisation.*

C. — VARIABILITÉ OPÉRANTE

Tous les travaux que nous avons mentionnés jusqu'à présent ont étudié l'expression de la variabilité spontanée et ses rapports avec un ensemble de variables liées à l'organisme et à l'environnement. Elle est influencée par l'état de cet environnement et par ses modifications. Cette variabilité de base, condition nécessaire aux apprentissages ultérieurs, est indissociable d'une pluralité de facteurs inhérents à l'organisme, tels que l'espèce (Parker, 1974), l'expérience antérieure et l'état physiologique (Devenport, 1983). Interrogeons-nous à présent sur la possibilité de conditionner la variabilité comportementale elle-même.

1 / Réponses simples

Schoenfeld, Harris et Farmer (1966) sont les premiers à avoir explicitement conditionné des variations du comportement. Ils ne renforcent des pressions de leviers chez des rats que si les intervalles inter-réponses appartiennent à une classe différente de celle de l'intervalle inter-réponses immédiatement précédent (l'exigence est ici minimale : les rats peuvent obtenir tous les renforcements programmés par la simple alternance de deux INT de durées différentes). Les résultats montrent l'effet escompté, ce qui incite les auteurs à fournir une « recette » pour l'étude de la variabilité opérante ». L'entraînement à la variabilité de la réponse est

affaire : *a)* de définition de la forme et du degré de variabilité désirés ; *b)* de mise au point des contingences de *renforcement* qui *créeraient* cette variabilité ; et *c)* d'insertion de ces contingences dans un programme de renforcement. » Mais des études *ultérieures montreront* que *la solution* n'est pas si simple.

Blough (1966) envisage la même variable dépendante et renforce systématiquement les intervalles inter-réponses les moins fréquents de ses pigeons. Il obtient des distributions aléatoires de cette dimension. *Bryant* et *Church (1974), pour obtenir* des *comportements* de *choix* aléatoires entre deux leviers, récompensent à 75 % les comportements d'alternance entre les leviers et à 25 % la répétition de la réponse sur un même levier — comportement « préféré » par les rats. Enfin, Pryor, Haag et O'Reilly (1969) conditionnent la variabilité de la topographie de la réponse chez des marsouins, en ne renforçant que les comportements dont la forme est différente de celle des comportements émis précédemment par l'animal. Ils obtiennent l'apparition de nouvelles conduites parmi lesquelles certaines n'avaient jamais été observées dans cette espèce.

Si le peu d'études réalisées indique de façon claire que la variabilité comportementale est sensible à ses propres conséquences, et peut se comporter comme n'importe quel autre aspect du comportement (durée, force, taux...), ces travaux souffrent cependant d'un biais méthodologique. Aucun ne contrôle les effets de l'intermittence du renforcement ; au fur et à mesure que l'entraînement se déroule, le renforcement n'est plus continu, mais devient intermittent. Or, nous avons montré que l'intermittence du renforcement a tendance à augmenter la variabilité spontanée, facteur qui est ici *indissociable* du *renforcement* direct de la variabilité. On pourrait, de même évoquer la succession de périodes d'extinction pour expliquer ces résu[illegible]s.

2 / Réponses complexes

Dans une tâche déjà décrite (matrice 5 × 5 lampes), Schwartz (1980 ; 1982 *a*) tente de conditionner la *variabilité* des séquences de réponses en renforçant une séquence correcte si elle est différente de la précédente (condition de variabilité minimale). Les pigeons, qu'ils *soient naïfs* ou expérimentés, développent une séquence qui devient dominante malgré les contingences de variabilité. Perikel (1982) observe des *comportements* similaires chez le rat dans une tâche adaptée à ces animaux (matrice 4 × 4 lampes ; 2 leviers-réponse). Schwartz (1982 *a*), émettant l'hypothèse que les *pigeons maîtriseraient* la contingence de variabilité si leur répertoire comportemental contenait au moins deux séquences de réponses, confronte des animaux expérimentés à deux situations d'apprentissage successives. Dans un premier temps, il les conditionne à alterner de manière stricte deux séquences de réponses particulières différentes durant 50

séances. Dans un second temps, il les place dans la condition de variabilité minimale (50 séances). Même si à la fin de la première phase et au début de la seconde, les pigeons tendent à produire les deux séquences de réponses avec la même fréquence, lors des dernières séances de la seconde phase, le comportement d'alternance se détériore et une séquence devient dominante. Et l'auteur de conclure : « ... alors qu'il est clair que le renforcement peut créer un répertoire de réponses variées bien que définies et circonscrites, il n'est pas clair qu'il peut accroître la variabilité *per se* » (Schwartz, 1982 *a*, p. 179)[5].

Pour Page et Neuringer (1985), la contrainte de la réponse définie par Schwartz (4 coups de bec sur chaque clé) explique son échec à conditionner la variabilité et entraîne une limitation des séquences possibles. Il n'y a que 70 séquences possibles contre 256 dans une situation où les huits coups de bec ne doivent pas être également répartis entre les deux clés. En supprimant cette contrainte ainsi que la matrice d'indices lumineux, ces auteurs conditionnent des pigeons à émettre des séquences de huit réponses sur deux clés disponibles. Les pigeons obtiennent plus de 70 % de renforcements possibles même si une séquence doit être différente des 50 précédentes. Les séquences ainsi émises sont comparables à celles que produit un générateur de nombres pseudo-aléatoire.

En contrôlant l'intermittence du renforcement (*yoked control design* : les renforcements sont donnés selon le même pattern temporel que précédemment, mais ne sont plus contingents à la variabilité des séquences), ils démontrent que la variabilité observée n'est pas une expression spontanée liée à l'intermittence du renforcement mais qu'elle est bien fonction des contingences de celui-ci. Ils mettent également en évidence que la variabilité peut être placée sous le contrôle d'un stimulus discriminatif (alternance d'exigence d'une séquence stéréotypée et d'exigence de variabilité). A la différence de Schwartz, Page et Neuringer montrent que la variabilité présente les caractéristiques d'un opérant, au même titre que d'autres dimensions de la réponse (force, localisation...). Lorsque des pigeons préalablement conditionnés à varier leurs séquences de réponses sont ensuite placés dans une situation identique à celle utilisée par Schwartz (matrice 5 × 5 ; 4 coups de bec sur chaque clé ; condition de variabilité minimale), ils obtiennent des résultats comparables aux siens (40 % des renforcements possibles). Toutefois, la cause du faible pour-

5. L'échec de cette tentative a des fondements méthodologiques. Dans la première phase, deux séquences particulières sont strictement renforcées alors que dans la condition de variabilité minimale toute séquence nouvelle l'est également. Cette discordance entre les deux phases produirait une interférence entre deux types d'opérant : d'une part, les deux séquences acquises devenues intégrées et, d'autre part, des séquences de réponses juxtaposées d'un niveau de complexité inférieur. Le renforcement des dernières interférerait avec celui des séquences alternantes (cf. Schwartz et Reilly (1985), pour une analyse détaillée du processus d'interférence).

centage de renforcement est différente : les pigeons de Schwartz échouent parce qu'ils ont tendance à répéter la même séquence, alors que pour ceux de Page et Neuringer, l'échec est dû à un cinquième coup de bec sur une des deux clés. En outre, les séquences de réponses émises par les pigeons de Schwartz se présentent comme des unités intégrées et insécables, alors que chez Page et Neuringer, les pigeons distribuent leurs réponses de manière quasi aléatoire. L'analyse des séances d'entraînement préalables à la situation de variabilité minimale permet d'expliquer la nature différente des séquences émises. Les pigeons de Schwartz développent dès ce stade une séquence de réponses fonctionnellement intégrée et non modifiable. En effet, dans la période d'entraînement, les pigeons doivent produire quatre coups de bec sur chaque clé sans exigence de variabilité, alors que chez Page et Neuringer, les pigeons sont d'emblée placés dans une situation où toutes les séquences de réponses produites aléatoirement sont renforcées, pour autant qu'elles soient différentes des précédentes.

A partir de ces résultats, quelques réflexions peuvent être faites à propos de la tâche utilisée par Schwartz. Si les animaux abordent la situation en émettant un ensemble de séquences de réponses « juxtaposées » variables et obtiennent peu de renforcements, ils ne peuvent optimaliser leur gain qu'en maîtrisant la tâche elle-même ; ce qui entraîne une diminution de la variabilité. Il est dès lors contradictoire d'exiger ultérieurement la variabilité du comportement quand il n'existe plus qu'une réponse intégrée sous une forme stéréotypée dans le répertoire de l'animal.

Un des auteurs de cet article (Boulanger, 1986) a réussi à conditionner la variabilité des séquences de réponses en veillant à ce que les pigeons ne puissent développer de séquences intégrées, tout en maîtrisant la contrainte de distribution égale des réponses sur les deux clés (matrice 4 × 4 lampes). Grâce à un préentraînement adéquat[6], il parvient à établir chez l'animal un répertoire de réponses caractérisé par des unités « minimales » différentes qui, en se combinant, permettent de résoudre la tâche de façon variée. Ce type de répertoire peut être considéré comme intermédiaire entre celui créé par Schwartz et celui des pigeons de Page et Neuringer. Cependant, même dans ce cas, le nombre de possibilités est encore fort limité.

D. — CONCLUSION

Si on reprend l'analogie avec la théorie de l'evolution, on pourrait affirmer, après cette brève revue de la littérature, que les données actuelles concernent plus les mécanismes sélectifs que les mécanismes de la variabilité comportementale. L'absence d'une cohérence au niveau des résul-

6. En allumant de façon aléatoire, au début de chaque essai, des lampes de plus en plus éloignées du but, il amène progressivement les pigeons à opérer des séries de discriminations successives.

tats empiriques est claire : ceux-ci sont parfois contradictoires, parfois non comparables, et inexistants dans certains domaines (le *shaping* ou les relations entre variabilité et émotions, par exemple). Les axes autour desquels les recherches sont organisées ne sont pas évidents, et les variables étudiées jusqu'à présent ont été « importées » de l'étude des mécanismes sélectifs (par ex. : renforcement, extinction, intermittence, etc.). D'autre part, cette même revue illustre la possiblité technique et méthodologique d'une étude de la variabilité en tant que variable (cf. Lepley, 1954).

Après le résumé des données expérimentales et de quelques problèmes spécifiques, un ensemble de réflexions générales et la présentation de quelques voies de recherche semblent s'imposer.

— Si le renforcement contingent à une dimension du comportement, comme la force ou la localisation, conduit à une diminution de la variabilité, le processus responsable de cet effet n'a pas été directement étudié. Plusieurs hypothèses ont été proposées à des niveaux différents :

a) Effet de la relation de contingence (renforcement différentiel), généralement non contrôlé par l'expérimentateur, entre certaines variantes de la réponse et l'obtention du renforcement ;

b) Effet des contiguïtés temporelles accidentelles entre certaines valeurs de la dimension comportementale envisagée (une durée particulière de la réponse, par exemple) et le renforcement, ce qui pourrait entraîner, de façon automatique, l'augmentation de la probabilité d'émission de réponses ayant cette durée. La stéréotypie serait alors l'effet de la répétition de ce cycle ;

c) A un autre niveau, cet effet serait dû à la maximalisation du rapport coûts gains énergétiques (au moins en ce qui concerne la durée, la force ou la latence de la réponse ; d'autres dimensions telles que la localisation ne se prêtent pas aussi aisément à cette interprétation).

Ces hypothèses n'étant pas équivalentes — telles qu'elles sont formulées — une recherche plus approfondie des processus qui réduisent la variabilité comportementale s'avère indispensable.

— La phase d'élaboration de *shaping* de la réponse est un moment privilegié d'interaction entre la variabilité et la sélection des comportements. Cependant, peu d'études ont été consacrées à ce processus (les travaux de Platt (1979) cependant, font l'exception).

— Une caractéristique commune à tous les travaux recensés est leur limitation à l'étude de la variabilité à l'intérieur d'une classe comportementale. De plus, l'attention a porté sur une seule dimension du comportement à l'intérieur de cette classe (par exemple, la force de la réponse opérante). L'élargissement des études à plusieurs classes et dimensions du comportement (Notterman et Mintz, 1965) contribuerait à clarifier les contradictions relevées dans les recherches publiées jusqu'à présent.

— Dans le cadre de la variabilité opérante, les quelques résultats présentés ci-dessus, qui exigent des réplications et extensions à d'autres comportements et à d'autres espèces, nous amènent à douter de la validité de certaines conceptions de l'apprentissage et du renforcement (telle que l'apprentissage conçu comme perte, puisqu'il réduit le potentiel de variabilité). Certaines expériences indiquent, par contre, que le renforcement n'induit pas nécessairement la stéréotypie et peut même augmenter la variabilité d'une classe opérante. L'étude de ce phénomène — renforcement différentiel de la variabilité — pourra fournir un outil important dans la compréhension de la flexibilité et du degré de différenciation possible des diverses classes comportementales (Pryor *et al.*, 1969). Dans ce contexte on peut penser qu'une des conditions nécessaires au conditionnement de la variabilité pourrait être l'existence, dans le répertoire de l'animal, d'éléments comportementaux différents, soit issus de variables phylogénétiques, soit acquis pendant l'ontogenèse. On devrait s'attendre à conditionner plus facilement la variabilité chez des individus qui présentent des répertoires comportementaux plus riches (Richelle, 1976 ; cf. également les travaux sur les « contraintes sur l'apprentissage »).

— Une des lacunes majeures de l'étude expérimentale de la variabilité est l'absence de travaux situés dans une perspective ontogénétique. Quelques auteurs (Teitelbaum, 1977 ; Segal, 1972) ont considéré que le comportement opérant se développe à partir du comportement réflexe présent aux premiers stades du développement. Des études similaires sur la variabilité comportementale seraient importantes puisqu'elles nous aideraient à clarifier les effets dus à l'exposition précoce à des environnements plus ou moins riches et ceux dus à des expériences plus ou moins variées.

Ces deux dernières remarques ouvrent de nouvelles perspectives de recherche, non seulement dans le domaine de l'apprentissage et du développement, mais aussi dans ceux de l'éthologie et de la psychologie comparée.

RÉSUMÉ

Le but de cette revue, qui dresse un bilan des connaissances relatives à la variabilité comportementale en conditionnement opérant chez l'animal, est d'ouvrir la voie aux recherches futures. Les recherches présentées sont organisées autour de deux axes : 1) L'examen de la variabilité spontanée de la réponse opérante en fonction de divers facteurs ; et, 2) L'étude des possibilités de renforcement sélectif des variations de la réponse opérante — variabilité requise. A l'issue de cette revue, il apparaît clairement que les mécanismes de variation ont été beaucoup moins étudiés que les mécanismes de sélection du comportement (mécanismes pourtant complémentaires en théorie de l'apprentissage). Quelques résultats laissent entrevoir

la possibilité de considérer la variabilité comportementale comme une dimension inhérente au compc·te nent, sensible aux contingences de renforcement, comme le sont la f··· la durée .

Mots clés : variabilité c · ·rtementale, conditionnement opérant, animal.

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Title: Operant conditioning of behavioral variability using a percentile reinforcement schedule

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Running head: Operant Variability

Abstract

The present investigation developed and tested a new Percentile Reinforcement Schedule (Platt, 1973), suited to study pattern variability, and whose main feature was the relative dissociation it provided between the variability requirement defining criterion responses and overall probability of reinforcement. In a discrete-trials procedure, pigeons produced patterns of 4 pecks on two response keys. If the pattern emitted on the current trial differed from the N preceding patterns, reinforcement was delivered with probability u. The schedule continuously adjusted the criterion N such that the probability of a criterion response, estimated from the subject's recent behavior, was always constant. In these circumstances, the criterion corresponded to a percentile point.

Using a between-subjects design, Experiment 1 manipulated the variability requirement - the percentile - while keeping reinforcement probability constant. It was found that the degree of variability directly varied with the requirement. In addition, an inverse relationship existed between the requirement and within-group variance. Experiment 2 manipulated probability of reinforcement while maintaining the variability requirement constant. No consistent relationship was found between variability and reinforcement probability. A tentative hypothesis was advanced ascribing the operant conditioning of behavioral variability to a process of <u>probability dependent selection</u>.

The Percentile Schedule presented some limitations, particularly when the subject's behavior was highly stereotyped.

Suggestions were made to overcome these limitations and further improve the schedule.

Key Words: operant variability, intermittent reinforcement, Percentile Reinforcement Schedule, key peck, pigeons.

OPERANT CONDITIONING OF BEHAVIORAL VARIABILITY USING A PERCENTILE REINFORCEMENT SCHEDULE

The usual procedure to condition behavioral variability involves the delivery of a reinforcer whenever the current response differs from one or more previously emitted responses (e.g., Morris, 1987; Neuringer, 1986; Page and Neuringer, 1985; Pryor, Haag and O'Reilly, 1969; Schoenfeld, Harris and Farmer, 1962). Results from these studies suggest that variability is a property of behavior that is sensitive to its consequences and, therefore, amenable to operant conditioning. However, when reinforcer delivery depends on variable responding, another source of response variability - the intermittency of reinforcement - is simultaneously present. That is, the effects of the operant contingency will probably be confounded with the effects of reinforcement intermittency (for a review of the effects of reinforcement intermittency on behavioral variability see Boulanger, Ingebos, Lahack, Machado and Richele, 1987). Therefore, no clear demonstration of the operant conditioning of behavioral variability is possible if the elicited effects of reinforcement intermittency are not adequately controlled . Page and Neuringer (1985, Experiment 5), were the only authors that adressed this problem using a self-yoked control design. Initially, pigeons were rewarded if their pattern of eight pecks to left and right response keys during the current trial differed from the patterns of the last 50 trials. This procedure engendered a high degree of behavioral variability. Next, the

sequence of reinforced and unreinforced trials, obtained in the last 6 sessions, was repeated without any variability requirement, i.e., variability was permitted but not demanded. Behavioral variability sharply decreased, notwithstanding the same intermittency of reinforcement. It was concluded that the initially observed variability was not a respondent effect of the schedule of reinforcement.

However, when the variability requirement is manipulated (see Page and Neuringer, 1985, Experiment 3, in which the criterion for reinforcement varied from 1, i.e., the current pattern had to differ from the preceding one, to 50, i.e., the current pattern had to differ from every pattern emitted on the last 50 trials) it is not clear what procedure should be used to control the associated changes in reinforcement frequency (in fact, in Page and Neuringer's experiment, no control was used). Second, the procedure does not allow the study of the effects of reinforcement frequency on <u>operant</u> variability. In other words, if the experimenter wishes to study the interaction between operant and elicited variability, he must be able to vary the frequency of reinforcement while keeping a constant variability requirement, the opposite of the first point. Nonetheless, in the procedure described above, frequency of reinforcement cannot be an independent variable because it is partially determined by the subject's behavior itself. Finally, an adequate control of the eliciting effects of intermittent reinforcement implies a constant probability of reinforcement throughout the session, i.e., on a trial by trial basis, and not only from session to session.

The yoked control design is a step in the right direction, but from the preceding analysis it is clear that a more appropriate procedure is needed (see also Church, 1966, for some intrinsic problems of yoked control designs). Such procedure must allow the manipulation of the variability criterion - from how many patterns must the current response differ from if reinforcement is to be delivered? - while simultaneously controlling the overall probability of reinforcement. Developing and testing such procedure was the main goal of the present research.

Probability of reinforcement can be adequately handled if the experimenter controls the probability of a criterion response. However, this is not possible if the criterion is kept physically constant because learning continuously changes the proportion of the subjects's behavior meeting the criterion. To elucidate the difficulty consider the situation described earlier that constituted the starting point of this research: in a discrete-trials procedure, pigeons are required to generate patterns of, say, 4 pecks on two response keys. The pattern produced on trial N is then compared with the patterns produced on trials N-1, N-2, etc., until a match is found. The number of intermediate patterns is the variability score of the current pattern. Another way to think about this task is to consider that only 16 sequences are possible (2^4). Consequently, the current sequence has most likely occurred in the past and the number of trials between its last occurrence and the present recurrence is the variability score of the current sequence. Assuming no sequential dependencies from trial to trial (see Bryant and

Church, 1974; Page and Neuringer, 1985), the probability of a particular variability score x is given by the geometric distribution

$$Pr(x) = p\,(1-p)^x \tag{1}$$

where p stands for the probability of a repetition, (see Figure 1).

INSERT FIGURE 1 ABOUT HERE

Greater variability means a smaller p and, when all sequences are equally likely, p is 1/16, .0625. If a fixed variability score is settled as a requirement to reinforcement, as in Page and Neuringer's (1985) experiments, then with a progressive increase in variability (e.g., from p=.15 to p=.0625 in Figure 1), the proportion of the pigeon's behavior meeting the criterion increases (the sum of all probability values at the right side of the criterion in Figure 1), and so does overall reinforcement probability (assuming that all criterion responses are reinforced). This problem is critical if the effects of different criteria are being compared because they will be interwoven with the effects due to concurrent changes in reinforcement frequency.

One alternative which allows control of reinforcement frequency is to adjust the criterion relative to the current level of variability being exhibited. In other words, increase (respectively, decrease) the criterion whenever the subject's behavior is becoming more (respectively, less) variable. In

addition, the magnitude of this adjustment is such that the expected probability of a criterion response, that is, the expected probability the next variability score will be more excessive than our criterion number, is always constant. To accomplish these two conditions, the distribution of the subject's recent variability scores is used as a sample from which an experimentally-specified percentile point is calculated. This percentile point will be the variability requirement on the next trial. By continuously updating the sample - dropping the old and adding the recent variability scores - and adjusting the criterion as specified, the procedure is able to handle the probability of a criterion response. This probability is the complement of the percentile (e.g., to obtain criterion responses with probability .3, the 70th percentile is chosen). In order to have different variability requirements the experimenter specifies different percentile values. Finally, to obtain a certain probability of reinforcement per trial, P(S+), the experimenter adjusts the conditional probability of reinforcement given a criterion response, P(S+/Cr), to the unconditional probability of a criterion response, P(Cr), according to Equation 2 .

$$P(S+)=P(Cr)*P(S+/Cr) \tag{2}$$

Thus, to obtain an overall probability of reinforcement, P(S+), of .3 having chosen the 40th percentile, i.e., P(Cr)=.60, the P(S+/Cr) would be set at .50. The schedule so defined corresponds to a Percentile Reinforcement Schedule (see Davis and Platt, 1983; Scott and Platt, 1985, and specially Platt, 1973, for a thorough discussion of Percentile Reinforcement Schedules).

In short, with this procedure the variability requirement is relatively dissociated from the overall probability of reinforcement. The remainder of this article presents two experiments where the effects on behavioral variability of both factors were independently assessed.

EXPERIMENT 1

Page and Neuringer (1985, experiments 3 and 5) not only found that variability increased when patterns unlike those produced during the N preceding trials were differentially reinforced, but also that the degree of variability directly varied with N. The present experiment attempted to reproduce this relationship between required and obtained variability using a Percentile Reinforcement Schedule that handles reinforcement probability constant.

METHOD

Subjects

The subjects were experimentally-naive homing pigeons (columba livia). Each pigeon was maintained at 80% (± 10 g) of its free-feeding body weight. Water and grit were continuously available in their home cages and a 12-hour light-dark cycle was in effect.

Apparatus

The experimental chamber was 32 cm along the sides and 45 cm high. The floor was wire mesh and all walls and the ceiling were plexiglas. The front wall was covered with black paper. The

chamber was located in a sound attenuating box and white noise was permanently present. A one-way mirror parallel to the front panel permitted observation.

The front wall was equipped with two centered response keys, 23 cm above the floor, 2.2 cm in diameter and 5 cm center to center. Directly below the keys a 4.5 x 7 cm hopper opening, 7 cm from the floor, permitted access to grain.

Each key could be illuminated with a 5-W orange light and a 100-W white houselight, permanently lit, was located on the ceiling of the outer box, 90 cm above the front wall. A 7.5-W white light illuminated the hopper when mixed grain was delivered. A force of 0.2 N on either response key operated a microswitch producing an audible click. All events were controlled and data were recorded by a Commodore 64 computer.

Procedure

Pretraining. Sessions were conducted daily at approximately the same hour (9:00 a m). All pigeons were trained to peck both keys under a modified autoshaping procedure developed by Schwartz (1980). After variable intertrial intervals (mean=60 s) one or both keys were randomly lit for 6 s after which reinforcement (4-s access to grain) was delivered. During reinforcement the keylights were turned off. If a peck occurred on an illuminated key, food was presented. Each session ended when 50 reinforcers had been delivered. Autoshaping lasted 4 or 5 sessions.

The experimental sessions ended after 100 trials. At the beginning of each trial, both keys were illuminated. A peck on either key turned off both keylights for a 1-s interpeck

interval. Pecks during this period reset the interval but were ignored for all other purposes. After 4 pecks, either reinforcement or timeout followed. Reinforcement consisted of 4-s access to grain during which the hopper light was lit, and both keylights were turned off. Timeout also lasted 4 s, the keylights were off but the house light remained illuminated. Pecks during the timeout reset the interval but had no other scheduled consequences. The only difference between the interpeck interval and the timeout was the duration of these events.

Before the experiment proper, a transition phase was implemented for 4 sessions. One key was randomly lit (and not both as in the experiment proper) until a keypeck occurred. The probability of reinforcement after 4 pecks was gradually decreased from 1 to .4 and the number of trials increased from 50 to 100. All other procedural details remained the same (see above). This phase also assured an adequate sampling of both response keys.

The Percentile Reinforcement Schedule. Whenever a sequence of 4 pecks was completed, it was given a variability score equal to the number of sequences intervening between the current sequence and the most recent one it matched (to a maximum of 50). If this variability score was greater than a criterion number, reinforcement was delivered with probability $u = P(S+/Cr)$. All other sequences ended in timeout. To control the probability of a criterion response, $P(Cr)$, the variability scores of the most recent 20 sequences were rank ordered, and the variability score corresponding to an experimentally-specified percentile was determined. The percentile was the one for which

the complement yielded the appropriate probability of a criterion response. Table 1 presents a hypothetical example, showing the absolute and the cumulative frequencies of each variability score in the last 20 trials.

INSERT TABLE 1 ABOUT HERE

Suppose that the 70th percentile is being used and the overall probability of reinforcement is set to P(S+)=.3. Thus, P(Cr)=.3 and, according to Equation 2, P(S+/Cr)=1. Counting from below to include 14=(20)(.7) variability scores gives us the criterion number for the next trial (5, in this case). As no ties exist, i.e., no more than one sequence had a score of 5, the next sequence will be reinforced if its variability score strictly exceeds 5. However, if the 25th percentile is being used, P(Cr)=.75 and the criterion will be set at 2. To have P(S+)=.3, the P(S+/Cr) is adjusted to .4. In this case some ties exist and so if the next sequence has a variability score (a) greater than 2, it will be reinforced with probability .4, (b) exactly 2, it will be reinforced with the desired overall probability, .3.

This algorithm was always used except when the criterion was zero. Whether ties were present or not, zero variability scores, i.e., repetitions, were never reinforced. Another decision concerned the maximum allowed criterion number. Suppose the criterion is set to 30. This means that the next sequence should differ from at least the preceding 30 patterns in order to be

reinforceable. Nonetheless, an 'impossible' situation would occur if all the 16 possible sequences were among the last 30. This 'impossible' situation is most likely if the subject's behavior is highly variable and a high percentile is currently being used. To prevent its occurrence, the maximum criterion number was set at 25 because the probability of emitting the 16 sequences on the last 25 trials, assuming random responding, is less then .01 (in fact, it occurred only once throughout the present experiments; in this case the criterion was set to the highest possible score). The slight underestimation of the probability of criterion responses stemming from this limitation, was thought to be meaningless.

In the first session, the first trial was followed by reinforcement and before the 20th trial had occurred the criterion was calculated from all previous scores without any adjustment of reinforcement probability. From the second session afterwards, the last 20 variability scores each subject produced in the previous session were loaded into the computer's memory and were used to compute the initial criteria. Also, the initial patterns of the current session were compared with the last patterns emitted on the preceding session until their corresponding variability scores were found. This meant that birds were from then on running a sort of a long continuous session.

For this experiment, 18 pigeons were randomly assigned to 4 groups (see Table 2).

INSERT TABLE 2 ABOUT HERE

For all groups $P(S+)=.3$ and the 25th, 50th, and 70th percentiles were used with groups III, II, and I. In Group IV no requirement was imposed, i.e., <u>all</u> sequences were eligible for reinforcement. This group permitted an assessment of the elicited effects of reinforcement intermittency in the absence of any variability requirement. If variability is a differentiable response property it was expected that Groups I, II, III, and IV would be ranked in this order on the variability measures. Subjects received from 20 to 32 sessions until mean variability scores were visually stable.

RESULTS

Figure 2 shows the number of reinforcers earned by each bird on each session (excluding the first one) and the 95% confidence intervals - normal approximation to the binomial distribution with mean equal to $30=(.3)(100)$ and standard deviation equal to $4.58=\sqrt{(.3)(.7)(100)}$.

INSERT FIGURE 2 ABOUT HERE

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Table 2 shows some summary statistics of these distributions. Observed values were close to, but slightly above, 30, the predicted value for all groups. This was most evident in groups I, II, and III. Standard deviations were also similar in groups II, III, and IV, but smaller in Group I. Several factors might account for these slight deviations, such as the previously mentioned underestimation of response probability for Group I, the sample size from which the criterion was calculated, the algorithm deciding what do to when ranks tied (see above), and even the computer's pseudo-random generator! In any case, the magnitude of these anomalies was not large enough to undermine the analysis that follow.

The mean variability score each bird obtained in the last 5 sessions (taken as a long session of 500 trials), is shown in Figure 3 (individual values are shown in Table 2).

INSERT FIGURE 3 ABOUT HERE

Random responding would produce a mean variability score of 15, the <u>expected</u> number of trials before repeating a particular pattern. An ANOVA by ranks (see Meddis, 1984) supported the idea that the amount of variability depended on the requirement - $Z=3.63$, $p<.001$ (specific alternative hypothesis, H1: $M4<M3<M2<M1$, where M4 means expected mean rank of Group 4, etc.). Group I generated highly variable behavior whereas four birds of Group IV (variability was permitted but not required), soon directed

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almost all pecks to one or the other key. Groups II and III produced intermediate degrees of variability.

Another useful measure of sequence variability is Uncertainty (U), derived from Information Theory (see Miller & Frick, 1949; Attneave, 1959; Page & Neuringer, 1985). U was computed according to the following equation

$$U = -\Sigma\, p_i * \log_2(p_i) \qquad (1)$$

where U means Uncertainty measured in bits, p_i stands for the probability of sequence i, and Σ means the sum for all 16 sequences. Uncertainty is maximal when the 16 patterns are all equally likely, i.e., each one having a probability of 1/16. In this case U=4 bits. Uncertainty is minimal if one pattern dominates all the others, i.e., only one sequence is emitted. In this case U=0. Figure 4 shows mean U values in the last 5 sessions.

INSERT FIGURE 4 ABOUT HERE

The trend was the same as in Figure 3, that is, variability was a negatively accelerated function of the requirement. Taken together, these findings are consistent with the results reported by Page and Neuringer, (1985).

Intersubject differences were another important aspect of the data (see Figures 3 and 4). The magnitude of these differences was inversely related to the requirement. Even when no variability was needed, birds #13 and #15 of Group IV still

maintained a certain amount of variation, whereas the other birds' modal sequence represented exclusive responding on one key, accounting from 80% to 92% of their behavior. Page and Neuringer (1985, Experiment 5) had already observed important intersubject differences when the variability requirement had been totally eliminated.

Birds #3 and #4 of Group III also maintained a high degree of variability in the presence of a very low requirement. Birds in this group showed a different kind of stereotypic behavior. For Bird #12 sequences LLLL and RLLL accounted for 60% of its behavior; for Bird #8, modal sequences revealed a 'switching stereotypy' (LLLL, RLLL, RRLL, and RRRL, accounting for 86%; the Bird scarcely switched from the left to the right key); for Bird #3, stereotypy was exhibited on the last peck of the sequence (79% of these pecks on the right key and only 21% of the left key). On the other hand, groups I and II showed a very small spread in individual subjects' data. The only stereotypical feature in Group II was a preference, in birds #5, #6 and #11, for the right key at the beginning of each sequence (from 61% to 63%). Birds in Group I generated highly unpredictable behavior. As an example, Figure 5 presents the frequency of each variability score for Bird #1 and the predicted values assuming random responding (see Equation 1).

INSERT FIGURE 5 ABOUT HERE

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A Chi square test showed no significant difference between the two distributions, $X^2(36)=37.44$, $p>.40$.

DISCUSSION

The Percentile Reinforcement Schedule performed appropriately. The probability of a criterion response was, in each case, close to the predicted value, and, consequently, the probability of reinforcement was adequately handled. The slight underestimation of response probability for Group I may be corrected by letting the maximum criterion number be determined on a trial by trial basis. More specifically, a check could be continuously made to see if the actual criterion, corresponding to P_{70}, was really attainable, that is, if it was possible to emit a sequence whose variability score would equal or exceed the criterion number. In this case, the criterion could be, on some trials, greater than 25 and still be a valid criterion.

Using a between-subjects design the present experiment demonstrated that different amounts of behavioral variability can be maintained by operant contingencies. With the exception of Page and Neuringer's (1985) study, no other research had adressed this important subject. In fact, an adequate theory of learning must decide whether to take behavioral variability as a fundamental behavioral dimension directly amenable to reinforcement, or as a secondary behavioral property, reducible to more basic processes (see Neuringer, 1986; Page and Neuringer, 1985; Schwartz, 1982). This is both an empirical and a theoretical question. If reinforcement is seen as strengthening behavior, that is, as increasing the probability of those

responses that produce it, how can this process engender variability? This theoretical question is dealt with in the General Discussion. In contrast, if variability is a by-product of more fundamental processes, what are these processes? The present experiment ruled out differences in reinforcement intermittency as the explanation of the differences in the asymptotic level of variability, but only further research can settle the issue.

The high degree of pattern variability maintained by some birds in the presence of a weak variability requirement (Group III), or even its complete absence (Group IV), is analogous to the situation found with other response dimensions when reinforcement is no longer response-dependent (e.g., Davis and Platt, 1983). The transition phase implemented before the experimental sessions (see Procedure), might have induced a degree of response variability that was, in some birds, adventitiously maintained during the experiment proper. The problem left unexplained in this formulation is the development of stereotypy in Groups III and IV: why was superstitious reinforcement of behavioral variation not equally effective in all groups?

Another plausible hypothesis is to argue (see Neuringer, 1986), that behavior was initially variable; whether it remained variable or not was a matter of how stringent was the current requirement. Weaker requirements are less effective in controlling behavior and this means that greater inter-subjects differences are predicted in these conditions. Similar conclusions were drawn by Scott and Platt (1985, Experiment 4).

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Using a Percentile Schedule in which reinforcer delivery was contingent on the location of a joystick displacement response emitted by rats, the authors also found greater within-group variance when the requirement to deliver reinforcement was less stringent. They concluded that "weaker contingency is in a sense weaker control of response location by food delivery and greater variability in individual performance is a concomitant of weaker control" (Scott and Platt, 1985, p. 167). The same could be said about the present results if 'pattern variability' replaced 'response location' in the preceding quotation. In other words, when a weak requirement was present, different variables might have controlled the performance of different birds. With stronger requirements, the influence of these other variables is greatly attenuated, and the requirement per se plays the major role (see also Crow, 1977 for a related hypothesis). Further research should clarify this topic and a possible starting point is the replication of the present experiment with a within-subjects design and an initially stereotyped baseline.

EXPERIMENT 2

Changes in reinforcement frequency have well-known if somewhat inconsistent effects on behavioral variability (e.g., Antonitis, 1951; Boren, Moersbaecher and Whyte, 1978; Eckerman and Lanson, 1969; Ferraro and Branch, 1968; Herrick and Bronberger, 1965; Herrnstein, 1961; Lachter and Corey, 1982; Millenson, Hurwitz and Nixon, 1961; Notterman and Mintz, 1965; Stebbins and Lanson, 1962; Tremont, 1984; and, for a review, Boulanger et al., 1987). However, no research has been conducted

to study the effects of changes in reinforcement frequency when variability is the response property on which reinforcement is dependent. In fact, elicited variability, a function of reinforcement intermittency, might interact with operant variability, a function of an operant contingency, and this is an area deserving future study. The Percentile Reinforcement Schedule, as previously defined, is well suited to study this interaction because its main feature is the relative dissociation it provides between the criterion defining the operant class (the percentile) and the overall probability of reinforcement.

When only criterion responses are elegible to reinforcement, the maximum probability of reinforcement is, obviously, the probability of these criterion responses, i.e., the complement of the percentile. This means that large changes in reinforcement probability can only occur if a low percentile is chosen. In the present experiment the 30th percentile was used and the overall probability of reinforcement varied from .3 to .7.

METHOD

Subjects and Apparatus

Eight experimentally-naive pigeons were randomly assigned to two groups of 4 birds each. The apparatus was the same as in Experiment 1.

Procedure

Autoshaping was as in Experiment 1. The 30th Percentile was used throughout the experiment and so, P(Cr)=.7. For Group LH (L=Low, H=High), P(S+/Cr) was initially set to .43 and then to 1.

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Hence, $P(S+)$ changed from $.3=(.7)(.43)$ to $.7=(.7)(1)$. For Group HL the reverse order occurred, i.e., $P(S+)=.7$ and then $P(S+)=.3$, thus controlling any order effect. Table 3 shows the number of sessions for each condition.

INSERT TABLE 3 ABOUT HERE

The transition phase (see above, Experiment 1, Procedure) was only implemented for Group LH.

RESULTS

Figure 6 shows the number of reinforced trials per session and the 95% confidence intervals for groups LH and HL.

INSERT FIGURE 6 ABOUT HERE

Obtained values closely matched predicted ones but some deviations are worth mentioning. The number of reinforced trials was too low in some sessions of Birds #3 and #8 when $P(S+)=.3$ and of Bird #6 when $P(S+)=.7$. These unexpected values strongly influenced the mean and standard deviation of their respective distributions (see Table 3). These anomalies were due to the following reason: deciding to not reinforce any repetition meant that, when behavior was highly stereotyped, the probability of a

criterion response was less than the predicted value. More specifically, when the probability of a zero variability score was greater than .3, the criterion remained at zero, but the probability of a criterion response was less than .7=1-.3, in as much as only variability scores <u>exceeding</u> zero were elegible to reinforcement. The algorithm applied when ties occurred with criterion values other than zero (see above, Experiment 1, Procedure), could not be used or the resulting intermittent reinforcement of repetitions would certainly produce maximal stereotypy (see results of Group IV in Experiment 1). This is, basically, a consequence of the discrete nature of the variability measure and its lower limit. Some suggestions will be given, later, to overcome this difficulty.

Mean variability scores in the last 5 sessions (see Figure 7) showed no consistent trend when reinforcement frequency was markedly changed.

INSERT FIGURE 7 ABOUT HERE

Some birds did not significantly alter their behavior (#4 and #8 from Group LH; #2 and #5 from Group HL). For other birds (#6 and #7 from Group HL), decreasing reinforcement frequency reduced response variability. In Group LH, increasing reinforcement frequency produced opposite effects for birds #1 and #3.

The mean Variability Scores obtained on each condition, i.e., P(S+)=.3 vs P(S+)=.7, were subjected to an ANOVA by ranks

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for related samples, with Subject as a blocking variable. No significant difference was found (K=12, p>.05). Mean Uncertainty scores gave exactly the same results.

Stereotypical patterns were similar to those observed in Experiment 1. As an example, Figure 8 shows, for Bird #1, U values for each keypeck in a sequence, viz., the Uncertainty of the first, second, third and forth pecks, considered as distinct events. On each case, only two possibilities exist, a left or a right peck. Hence, according to Eq.2, U is maximal, and equal to 1, when P(L)=P(R)=.5.

INSERT FIGURE 8 ABOUT HERE

It can be seen that, on some sessions when P(S+)=.3, a systematic preference for one response key was clearly shown on the first peck, all successive pecks remaining highly variable. A different picture is visible when P(S+) changed to .7 (the arrows in Figure 8). Stereotypy of the first peck gradually increased until, on session 37, 99 of the 100 sequences started on the left key. On session 39, the second peck was also highly stereotyped. From then on, a different pattern emerged whereby variability was confined to the first peck, all successive pecks being frequently emitted on the same key. In other words, when P(S+)=.3, variability increased from the first to the last peck; when P(S+)=.7, the reverse occurred, that is, variability decreased from the first to the last peck.

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Other birds (e.g., #2 when P(S+)=.3 and #5 when P(S+)=.3 as well as when P(S+)=.7) maintained a strong preference for one particular key on the first and/or second peck of each sequence. 'Switching stereotypy' was also displayed by Bird #3 when P(S+)=.3 (sequences LLLL, LLLR, LLRR (23%), LRRR (23%) and RRRR accounting for 72% of its behavior). No conclusion could be drawn relating frequency of reinforcement to kind of stereotypy.

DISCUSSION

Important changes in reinforcement frequency did not produce consistent changes in the level of variability. This finding is not completely unexpected since it parallels the results obtained when variability is not the response dimension defining the operant class. Whereas several authors have found an increase in variability when reinforcement becomes less frequent (Eckerman and Lanson, 1969; Ferraro and Branch, 1968; Herrick and Bronberger, 1965; Lachter and Corey, 1982; Stebbins and Lanson, 1962; Tremont, 1984), others did not find a similar result (Boren, Moersbaecher and Whyte, 1978; Herrnstein, 1961; Milleson, Hurwitz, and Nixon, 1961. See Boulanger et al. for possible interpretations of these inconsistent findings). In the present situation, several factors might have obscured the effects of reinforcement frequency. One of them is the timeout that might have gained discriminative control over the initial peck of each sequence. Due to its contiguity with timeout, the initial peck of a reinforced sequence could be more easily remembered and thus repeated. This in turn would result in more sequences beginning with this peck being reinforced, originating a positive feedback

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loop. This process might account for the increased stereotypy of Bird #1 when P(S+)=.7. A direct implication of this analysis is the elimination of the timeout in future investigations designed to study the effects of reinforcement frequency on operant variability.

That timeout cannot be the only variable at play is suggested by the presence of other types of stereotypy (e.g., variability confined to the first peck). Furthermore, not all birds developed the same type of stereotypy. Further research is needed to clarify this topic.

The percentile schedule presented some problems when performance became highly stereotyped, that is, when the probability of a repetition exceeded the chosen percentile value, viz., .3. On these occasions, due to non-reinforcement of repetitions, a positive correlation existed between variability and reinforcement frequency. This correlation was maintained until the probability of a repetition was less than the percentile value. One solution to this problem is to increase the number of pecks making up a sequence. When this happens, the same probability of a Right (respectively, Left) keypeck will considerably reduce the probability of a repetition.

GENERAL DISCUSSION

The present experiments attempted to develop and test a new Percentile Reinforcement Schedule suited to study pattern variability. The main feature of the schedule should be the dissociation between overall probability of reinforcement and the criterion defining the operant class. This would enable the

experimenter (a) to maintain reinforcement intermittency constant while varying the variability requirement (Experiment 1), and (b) to maintain the requirement constant while varying reinforcement intermittency (Experiment 2).

Despite some deviations from predicted performance, the schedule successfully achieved its main purposes. In Experiment 1, the requirement varied among groups while the overall probability of reinforcement was held approximately constant. A suggestion was made to improve the schedule performance when a high percentile is used: adjust the maximum criterion number on a trial basis. In Experiment 2, the requirement was kept constant while the probability of reinforcement changed. The Percentile Schedule presented some limitations when the probability of a repetition was greater than the chosen percentile. Thus, the probability associated with the chosen percentile sets an upper limit to p, the probability of a repetition; when p exceeds this value, reinforcement probability will also be determined by the subject's behavior. This fact is, possibly, the most serious drawback of the schedule precluding the use of low percentiles (e.g., P10). One solution, as previously stated, is to increase the number of pecks per sequence.

Whatever the algorithms used to improve the schedule performance, it should be stressed that the aforementioned 'deficiencies' stem mainly from the nature of the variability measure itself: it is <u>indirect</u> (variability scores are dependent on the probability of a repetition - see Eq.1 - that in turn depends on the probability of each sequence); it is a <u>discrete</u>

measure, and has a lower limit, these last two features creating the problem of ties, specially of zero variability scores. These shortcomings in mind, the variability data will be commented upon now.

From Experiment 1 it was concluded that a weak percentile only moderately controls the amount of generated variability. Thus, a large change in reinforcement frequency could, theoretically, have shown its effects during Experiment 2. However, no consistent effect could be ascribed to reinforcement probability *per se* or, in other words, to the eliciting effects of intermittent reinforcement,when an operant contingency is present. Other variables (e.g., timeout) might have competed with frequency of reinforcement obscuring any effects this variable may have. Further research should refine the actual procedure (e.g., eliminate the timeout) and repeat the experiment with other combinations of percentile and reinforcement probability values.

Despite important within-group differences, results from Experiment 1 showed that variability directly increased with the requirement, a conclusion already reported by Page and Neuringer, (1985). The basic 'problem' of this finding has previously been raised by several authors (e.g., Page and Neuringer, 1985; Schwartz, 1982) and was briefly alluded to earlier: how can reinforcement maintain bahavioral variation if it increases the frequency of the class of behaviors producing it? Another way to raise the problem is to ask "What objective property of responses [on which reinforcement is dependent] would unite them into a class ?" (Schwartz , 1982, p. 178). It could be argued that, on

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each trial, a certain number of sequences, if generated, would yield variability scores greater than the criterion. Hence, this was the defining property on which reinforcement was dependent. The problem with this strictly operational definition derives not from its relational character but rather from the underlying behavioral process it assumes. In fact, the question asked by Schwartz is about behavioral processes, not about procedures (see Catania, 1973). More specifically, the answer takes for granted that pigeon's behavior is somehow sensitive to the dimension 'being different from X previously emitted patterns'. This assumption is unlikely given the difficulty pigeons have remembering sequences, beyond the trivial LLLL and RRRR patterns.

Page and Neuringer (1985), and Neuringer (1986), circumvented the question raised by Schwartz, by considering variability a fundamental behavioral dimension, such as force or duration, and by stressing the <u>shaping</u> in place of the <u>strengthening</u> effects of reinforcement: "When the experimenter shapes keypecking (...) the pigeon is taught where, when, and possibly how fast or hard, and so on, to peck. Analogously, there may be a dimension of all behaviors, described as <u>variability</u>, with which the organism enter our experiments (...) Turning on of off a variability generator may be under the control of reinforcement, but the variability generator is not itself created through reinforcement." (Page and Neuringer, 1985, p. 450). The relationship between level of variability and degree of requirement is further viewed as a fine tuning of this inborn

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variability generator by the current contingencies of reinforcement.

Whatever the adequateness of this conceptualization, the hypothesis of a more basic behavioral process underlying the operant conditioning of behavioral variability has not been fully appreciated. Intermittent reinforcement has been one possibility, but the present results did not support it. In the following lines an alternative will be presented that assigns operant conditioning of response variability to a process of probability dependent selection. Experiment 1 suggested that overall probability of reinforcement does not play the major role in the process of variability differentiation. However, we are still left with the (conditional) probability of reinforcement per pattern. Consider what happens to the probability of reinforcement - P(s+) - associated with a particular sequence after it has been emitted. Whatever the requirement, P(s+)=0 on the next trial since no repetition is ever reinforced. When a low Percentile is chosen, after a few trials without emitting the sequence, P(s+) equals P(S+/Cr) whereas when a high Percentile is used, more trials have to elapse before the pattern is considered criterional again, and P(s+)=P(S+/Cr). On every trial, then, the stronger the requirement the smaller the subset of all reinforceable sequences. Also, this smaller subset will more likely be restricted to the momentarily least-probable patterns. Stated differently, increasing percentile values assure differential reinforcement of increasingly less-probable patterns. A similar idea is found in Blough's (1966) least-frequent IRT reinforcement schedule.

If this interpretation is valid, variability should not be considered a fundamental, i.e., an irreducible behavioral dimension, but the outcome of more primary processes, such as probability dependent selection. We posit that probability dependent selection underlies the operant conditioning of behavioral variability. This hypothesis predicts random responding as the asymptotic performance when stronger and stronger requirements are used. In the limiting case, all patterns will be equally likely and, consequently, equally reinforced.

The resemblance with the process of frequency-dependent selec ion is obvious. Curiously enough, a similar problem has been raised in the context of the Darwinian evolutionary theory: is a reduction of genotypic variability the only possible outcome of natural selection? The process of frequency-dependent selection shows that, under certain circumstances, the outcome of natural selection may be the maintenance of genetic variation, even in a constant homogeneous environment (Shorrocks, 1978).

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FOOTNOTES

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TABLE 1

Hypothetical data showing how to calculate the criterion. See text for details.

	Variab. Scores	Abs. Freq.	Cumulat. Freq.
	0	2	2
	1	1	3
P_{25}	2	3	6
	3	5	11
	4	2	13
P_{70}	5	1	14
	6	1	15
	...	...	...
	49	0	19
	50	1	20

TABLE 2

Experimental conditions for each Group and obtained results. Mean variability scores were based on the last 5 sessions. P(S+)=.3 for all Groups.

Group	Bird	P(Cr)	P(S+/Cr)	Sess.	Reinforcements mean'	Reinforcements s.d.'	Mean Variability Score
I	#1	.3	1	30	31.7	2.19	14.11
	#7	.3	1	30	32.0	2.17	14.06
	#9	.3	1	31	31.7	2.43	13.80
	#10	.3	1	24	32.2	2.47	13.64
II	#2	.5	.6	31	31.3	4.40	14.12
	#5	.5	.6	32	31.6	4.63	13.24
	#6	.5	.6	30	32.4	4.40	12.30
	#11	.5	.6	30	31.6	4.62	13.75
III	#3	.75	.4	31	31.6	4.56	11.70
	#4	.75	.4	31	31.6	4.87	12.08
	#8	.75	.4	30	30.9	5.01	7.22
	#12	.75	.4	29	31.2	5.00	8.10
IV	#13	1	.3	25	28.5	4.76	10.34
	#14	1	.3	20	28.6	3.66	2.33
	#15	1	.3	26	29.3	3.54	10.37
	#16	1	.3	20	30.6	4.10	3.19
	#17	1	.3	20	30.1	5.53	3.35
	#18	1	.3	26	29.9	3.80	4.03

' First session not included.

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TABLE 3

Experimental conditions for each Group and obtained results. Mean variability scores are based on the last 5 sessions. P(Cr)=.7 troughout Experiment 2.

		P(S+)=.3*				P(S+)=.7*			
			Reinforcement		mean variab.		Reinforcement		mean variab
Group	Bird	Sess.	mean**	s.d.**	score	Sess.	mean	s.d	score
	#1	26	29.0	2.86	13.38	29	68.4	4.04	7.43
	#3	30	25.4	5.15	10.20	25	69.4	2.71	12.92
LH	#4	27	28.5	3.37	13.76	15	69.9	2.49	13.58
	#8	27	26.3	5.64	13.31	20	69.9	2.10	13.28
	#2	25	31.7	5.51	12.01	27	68.8	3.62	11.87
	#5	20	30.1	4.97	9.46	28	69.4	2.88	9.91
HL	#6	20	30.4	3.49	9.70	29	67.2	6.26	13.15
	#7	25	30.8	5.13	12.60	24	68.8	3.28	13.84

* For Group LH, P(S+) was initially .3 and next .7. For Group HL, the reverse order occurred, i.e., P(S+)=.7 and later P(S+)=.3

** First session not included in Group LH when P(S+)=.3.

FIGURE CAPTIONS

Figure. 1 Probability distribution of variability scores when performance is random (probability of a repetition $p=.0625$) or stereotyped ($p=.15$, for example). Scores greater than the criterion are followed by reinforcement.

Figure. 2 Number of reinforcements earned by each Bird on each session. Dashed lines show the confidence interval, viz., $\pm$ 1.96 σ, of the expected number, viz., 30.

Figure. 3 Mean variability score as a function of the percentile. (Dots = averages over the last 5 sessions for each subject; solid line connects the mean of each Group). Variability was permitted but not required in Group IV, corresponding to Percentile [0].

Figure. 4 Uncertainty as a function of the percentile. (Dots represent averages over the last 5 sessions for each subject; the solid line connects the mean of each Group).

Figure. 5 Dots represent the frequency distribution of variability scores obtained with Bird #1 on the last 5 sessions. The last dot corresponds to scores greater than 49. The solid line connects the expected frequencies assuming random responding (see Equation 1). A Chi square test showed no significant difference between the two distributions, $X^2(36)=37.44$, $p>.40$.

Figure. 6 Number of reinforcements earned by each bird on each session. For birds #1, #3, #4, and #8, P(S+) was initially .3 and then .7; for the other Birds, the reverse order occurred. Dashed lines show the confidence interval, viz., $\pm$ 1.96 σ, of the expected number, viz., 30 when P(S+)=.3 and 70 when P(S+)=.7 Data from one session of Bird #3 and two sessions of Bird #8 were lost.

Figure. 7 Mean variability score obtained with each bird on the last 5 sessions of each condition. For birds #1, #3, #4, and #8 (left), P(S+) was initially .3 and then .7; for the other Birds (right), P(S+)=.7 and later .3.

Figure. 8 Uncertainty of each keypeck (left figure = first and second pecks; right figure = third and forth pecks) obtained with Bird #1 when P(S+) was .3 (to the left of the arrows) and .7 (to the right of the arrows)

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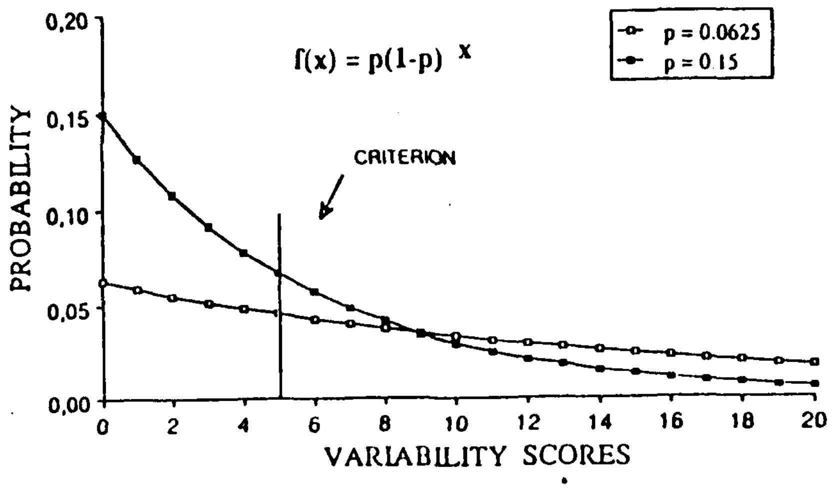

f(x) = p(1-p) x
p = 0.0625
p = 0.15
CRITERION
PROBABILITY
0,20
0,15
0,10
0,05
0,00
0
2
4
6
8
10
12
14
16
18
20
VARIABILITY SCORES

FIGURE 1

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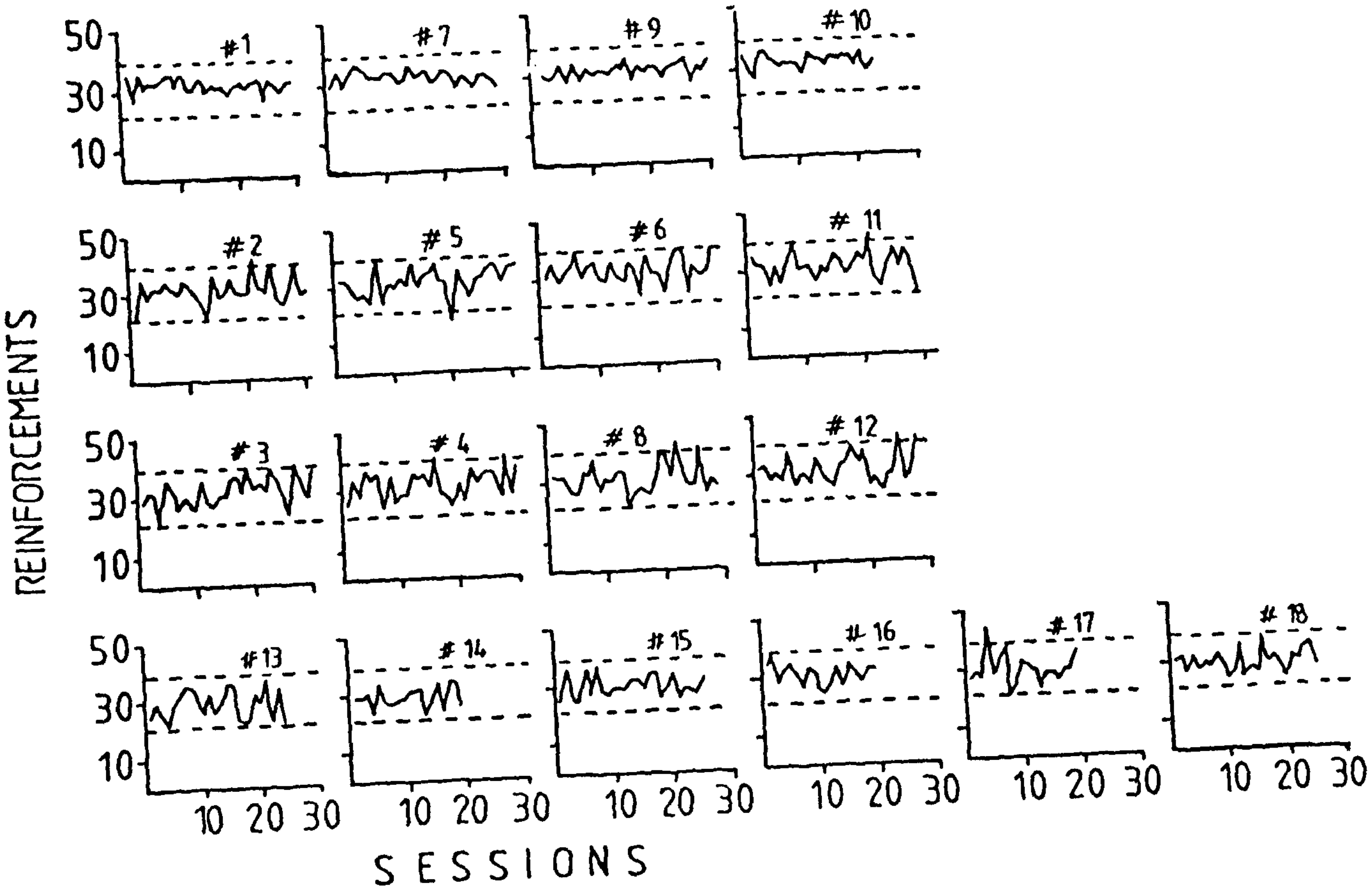


REINFORCEMENTS
50
30
10
#1
#7
#9
#10
#2
#5
#6
#11
#3
#4
#8
#12
#13
#14
#15
#16
#17
#18
10 20 30
SESSIONS

FIGURE 2

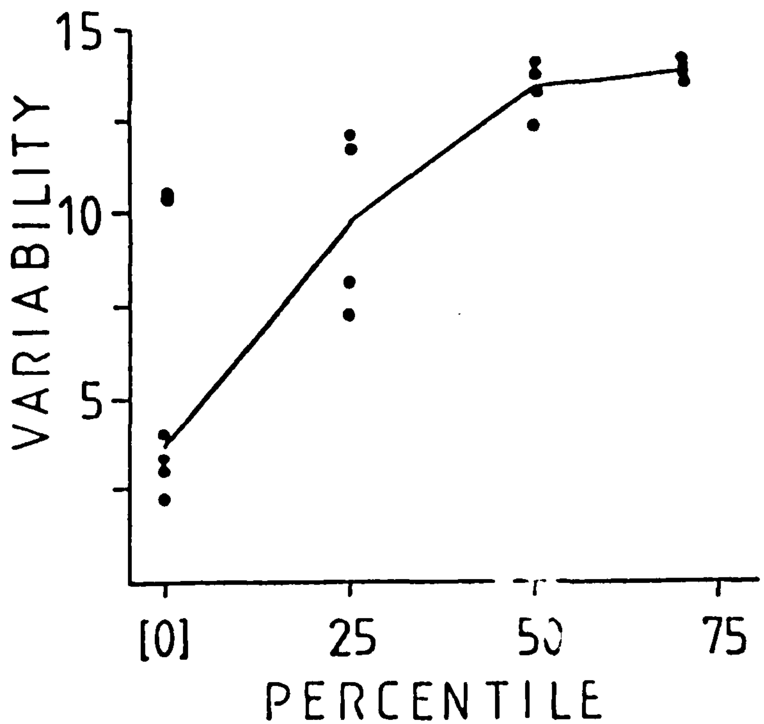


FIGURE 3

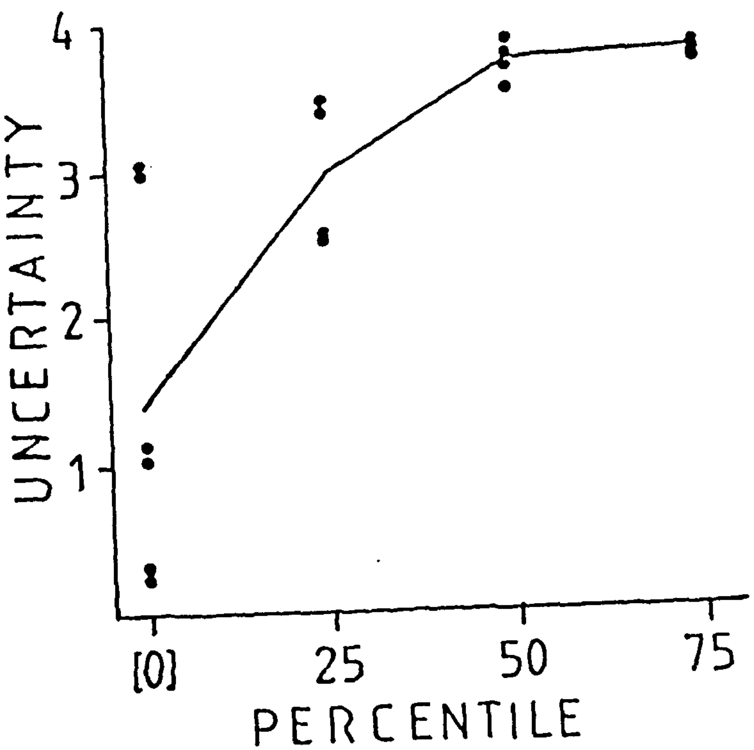
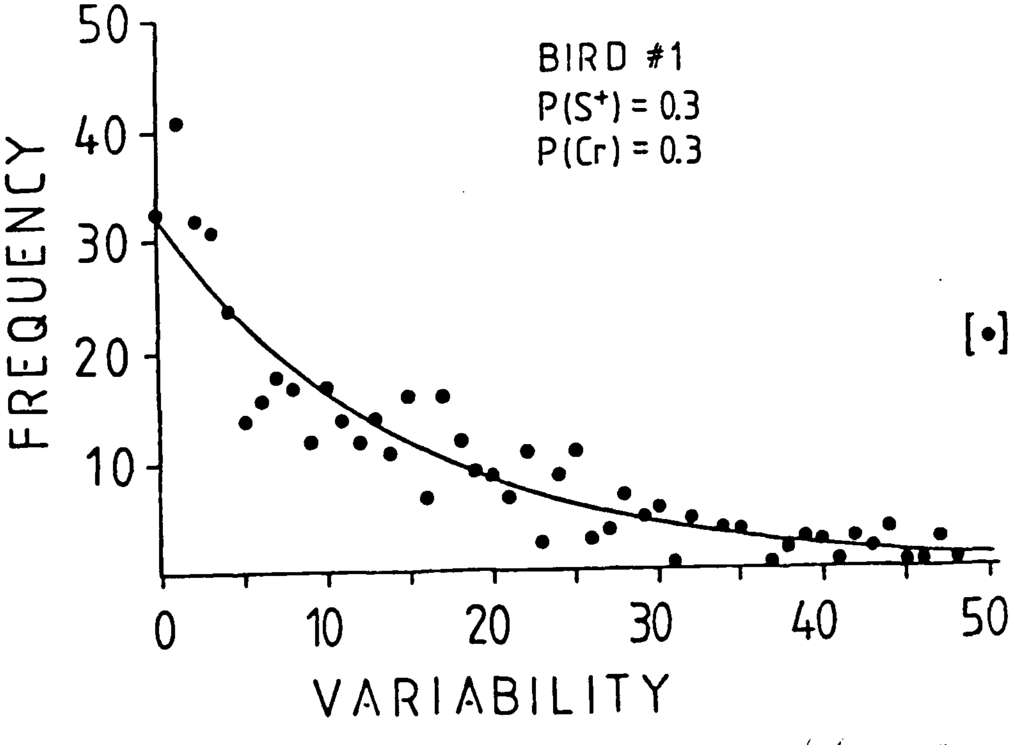


FIGURE 4

FIGURE 5



BIRD #1
P(S+) = 0.3
P(Cr) = 0.3
[•]
FREQUENCY
50
40
30
20
10
0
10
20
30
40
50
VARIABILITY

4 - 5

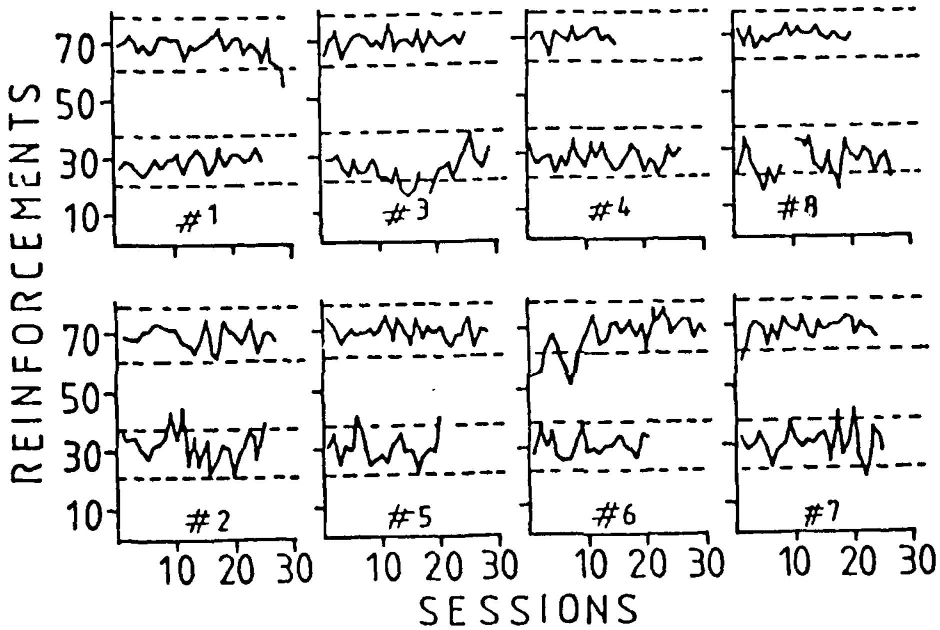


FIGURE 6

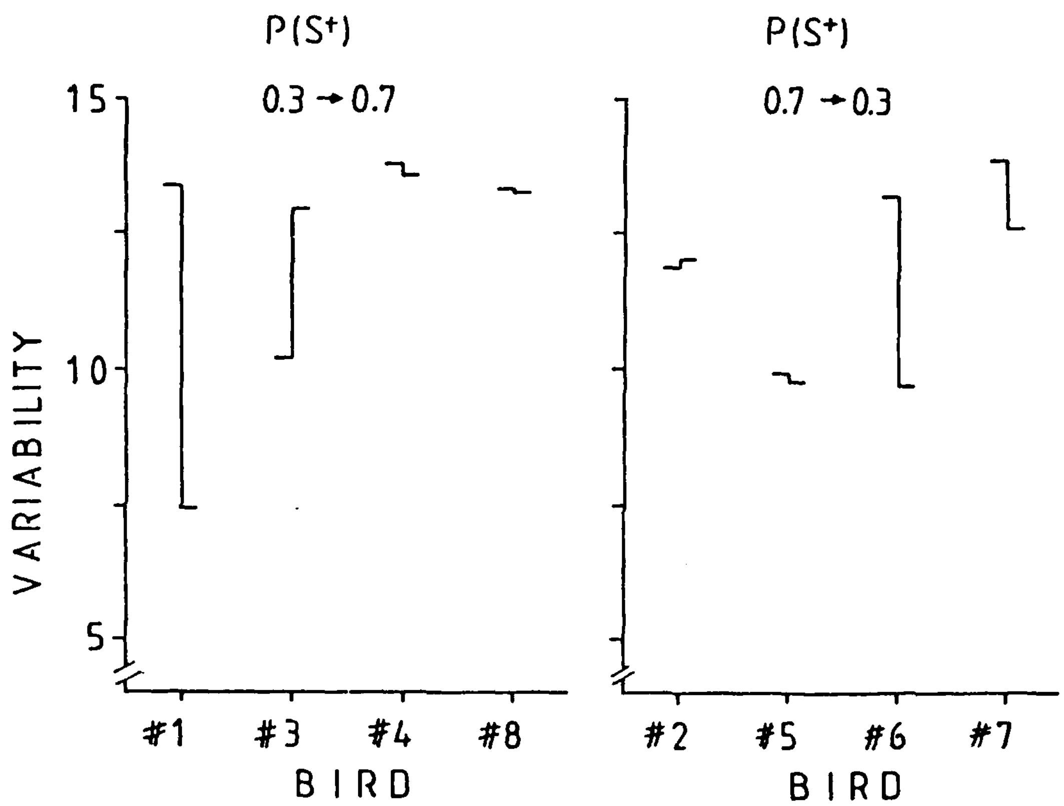


FIGURE 7

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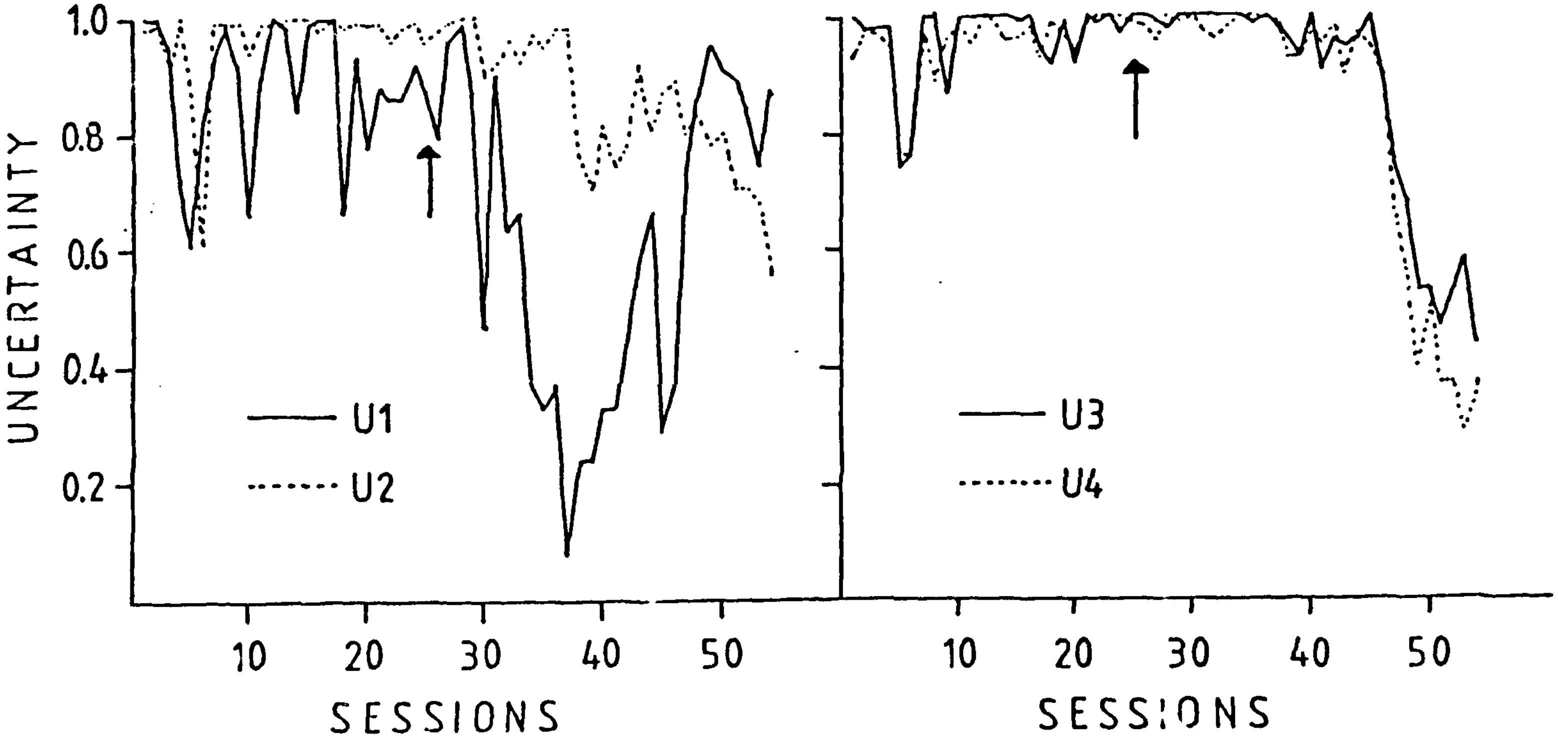

FIGURE 8